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LOCATION AND MOVEMENT ANALYSIS SYSTEM (LAMAS).(U)
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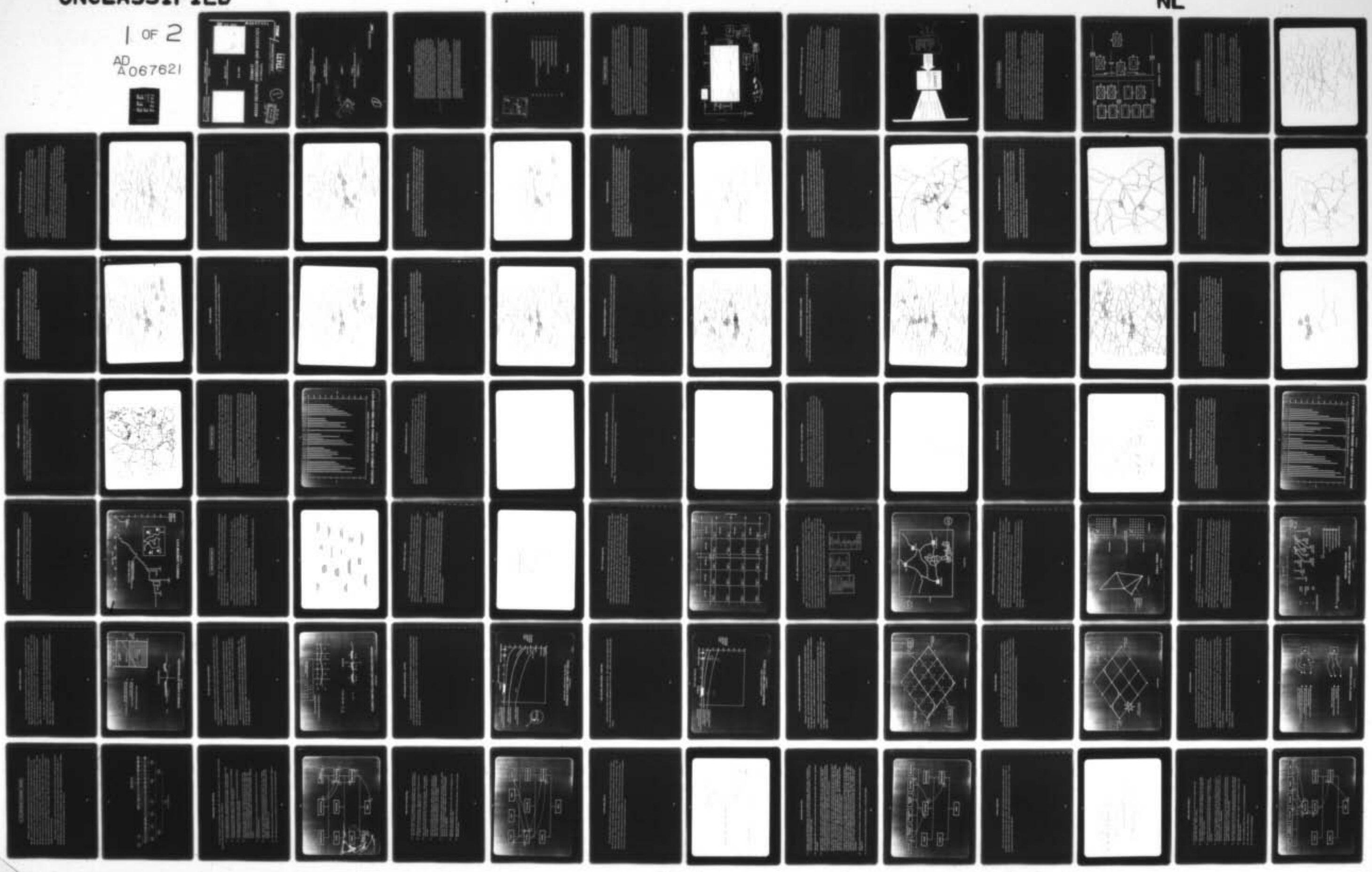

LEVEL II

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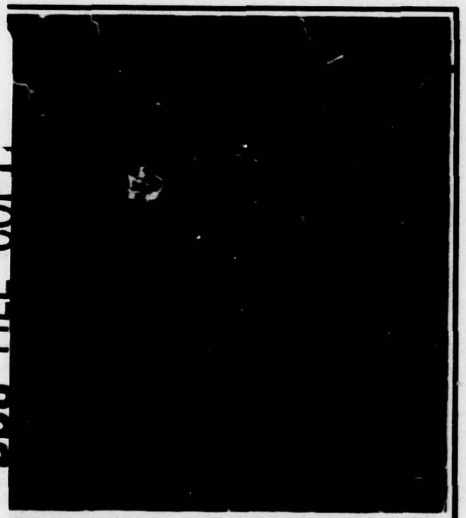
(1)

Final Report for

LOCATION AND MOVEMENT ANALYSIS SYSTEM (LAMAS)



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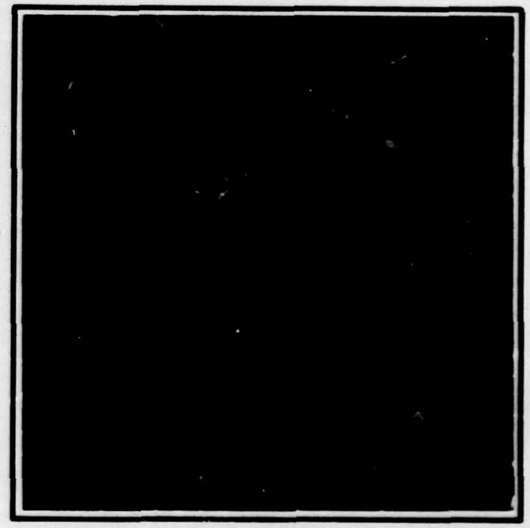

Prepared for
UNITED STATES ARMY INTELLIGENCE CENTER AND SCHOOL
FORT HUACHUCA, ARIZONA

(1)

TRW.
ADVANCED STUDIES
ONE SPACE PARK · REDONDO BEACH · CALIFORNIA 90278

(9) Final Report

(6) LOCATION AND MOVEMENT ANALYSIS SYSTEM
(LAMAS)

(11) June 1978

(12) 102p.

(15) CONTRACT NO. DAAG39-77-C-0112
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Prepared for
UNITED STATES ARMY INTELLIGENCE CENTER AND SCHOOL
FORT HUACHUCA, ARIZONA

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PREFACE

LAMAS is a computer-based system built at a prototype level to evaluate battlefield command support decision processes. The system was designed and built by TRW under contract to the United States *Army Intelligence Center and School* (USAICS). Contract objectives were centered on the support of corps-level commands regarding the location and disposition of enemy forces. A European setting at the Fulda Gap was selected and modeled in depth. The CACDA Command and General Staff College enemy order of battle was used along with other scenarios and situations to measure LAMAS performance. This report describes the resultant set of simulated command decisions indicated by LAMAS operating against the CACDA scenario. First

was made.

The LAMAS contract began with an analysis of enemy force movement doctrine. Mathematical foundations were derived to model these movements and then they were translated into computer algorithms and files. Prototype software was built to operate on a minicomputer of the size anticipated for future battlefield use—the PDP-11/45 and the ruggedized PDP-11/60. A self-imposed design constraint to maximize user visibility and interaction was adopted.

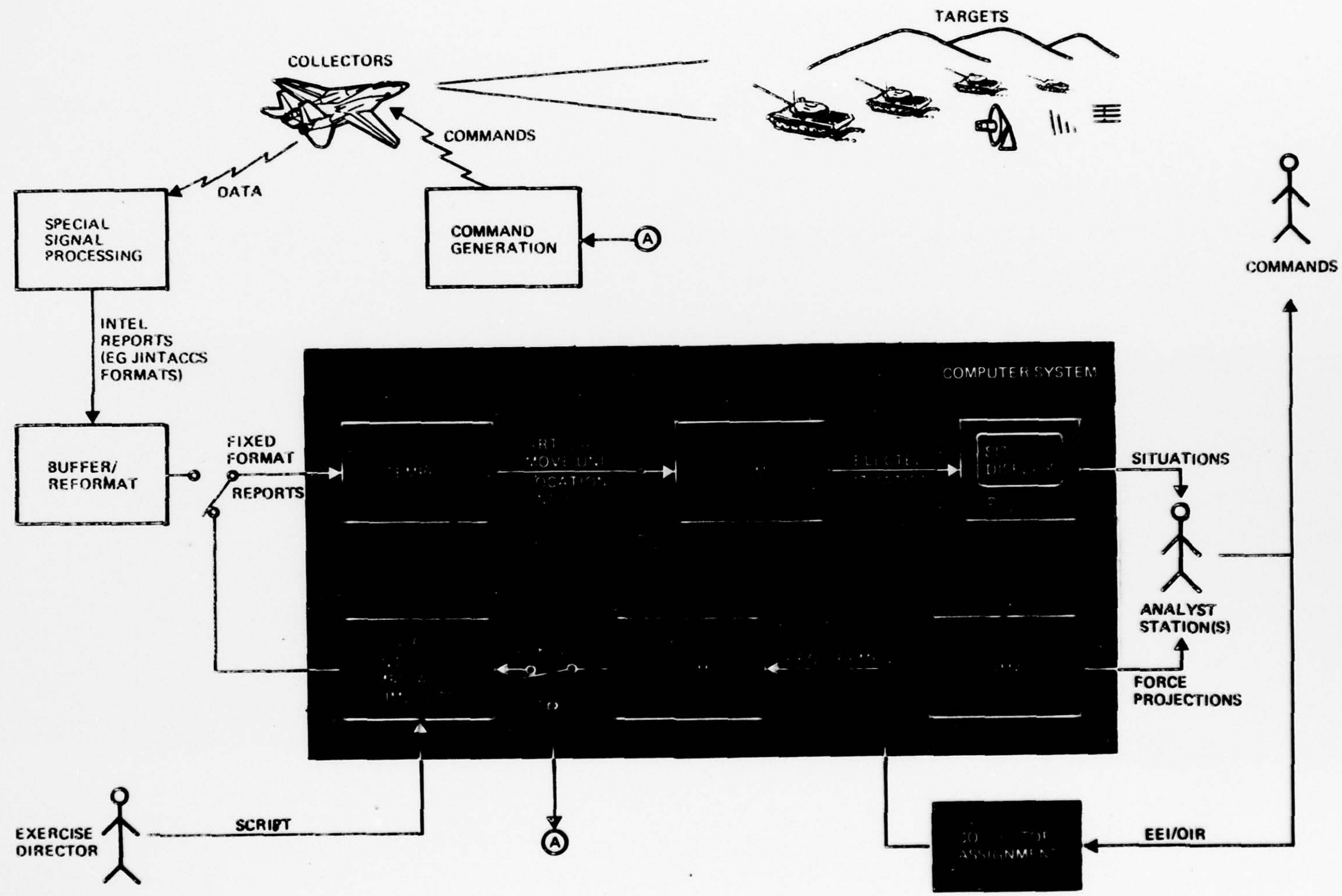
LAMAS performance has demonstrated that (a) crucial decisions can be made with tactical timeliness and high reliability when used as a battlefield tool and (b) preengagement analysis such as intelligence preparation of the battlefield ~~(IPB)~~ can be efficiently and accurately performed.

CONTENTS

1. COMMAND SUPPORT NEEDS

LAMAS is a command support applications tool. It represents one of several tools necessary to assess the enemy location and intent of forces. The facing diagram shows intelligence information flowing from friendly collectors to computer-aided enemy situation analysis stations. The intelligence data are first routed and fused by a function called TEMPRO to develop enemy unit locations and identifications. TEMPRO draws upon stored templates and operator/analyst knowledge to perform its functions. LAMAS operates on the enemy unit locations and identifications to project the locations ahead in time according to enemy doctrine and the tactical situation.

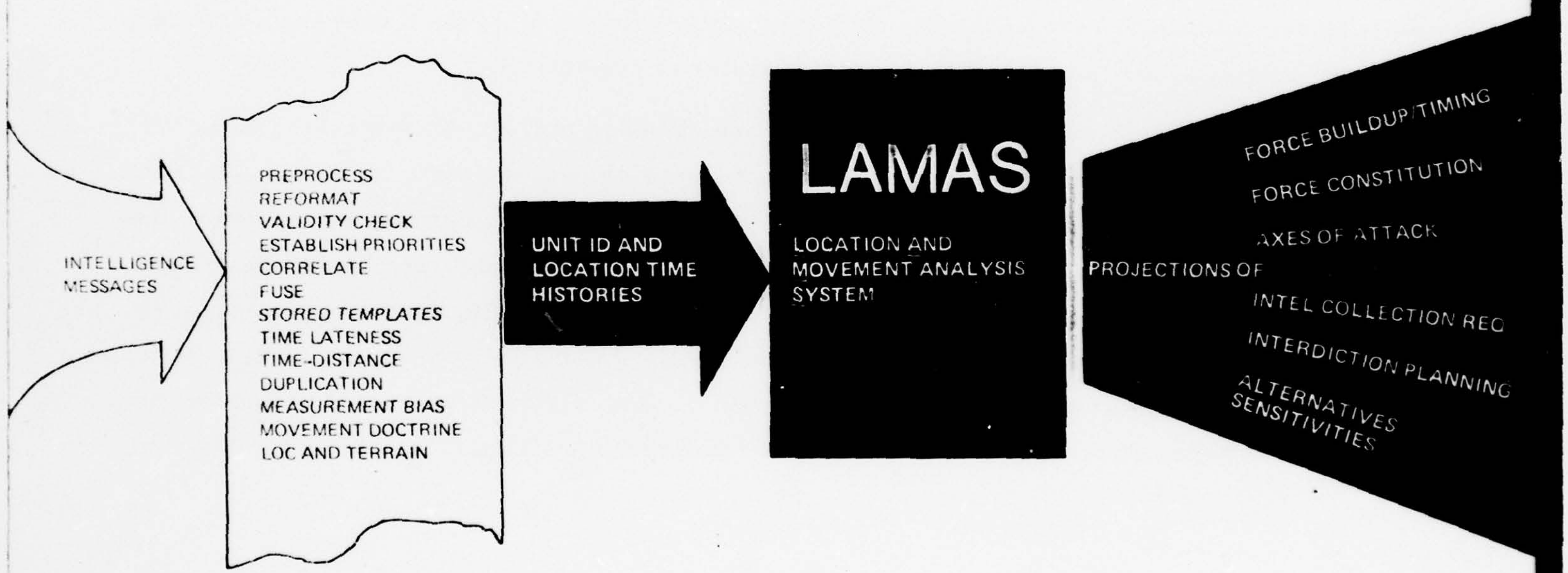
Projecting enemy unit locations ahead in time is necessary in order to know where and when the enemy axes of attack may occur so that friendly force maneuvers and offensive action can be planned. The projection also enables the tasking of intelligence collection assets to acquire relevant future data. EEIs, OIRs, and specific intelligence requests flow to ACOMS, a function which sorts and optimally assigns the requests to collectors. TEMPRO and ACOMS are currently under development by TRW.


TARGETS
COLLECTORS
COMMANDS
DATA
SPECIAL SIGNAL PROCESSING
COMMAND GENERATION
A
COMMANDS
INTEL REPORTS (EG JINTACCS FORMATS)
COMPUTER SYSTEM
BUFFER/ REFORMAT
FIXED FORMAT REPORTS
SITUATIONS
ANALYST STATION(S)
FORCE PROJECTIONS
EXERCISE DIRECTOR
SCRIPT
A
EEI/OIR

LAMAS PROJECTS ENEMY FORCE ELEMENTS AHEAD IN TIME

Intelligence that has been processed to develop a situation assessment represents position knowledge of the enemy at the time of data collection. The difference between the time of data collection and the current time varies between tens of minutes and hours. This time delay is caused by normal handling, interpreting, and processing. Thus, a commander must extrapolate his intelligence data ahead in time to project enemy force elements to current time. Projection to future time is also necessary in order to plan his friendly force deployments, sensor tasking, and interdiction.

Projections of enemy forces using LAMAS are made according to movement doctrine, lines of communication (LOCs) and cross-country trafficability, weather, time of day, threat of air attack, and other factors. The system output consists of color displays and alphanumeric data showing the projected threat. Special functions can be called by the operator to determine, for example, the best times and locations for air interdiction. Uncertainties in the projections are identified as areas of future intelligence asset tasking, as desired.

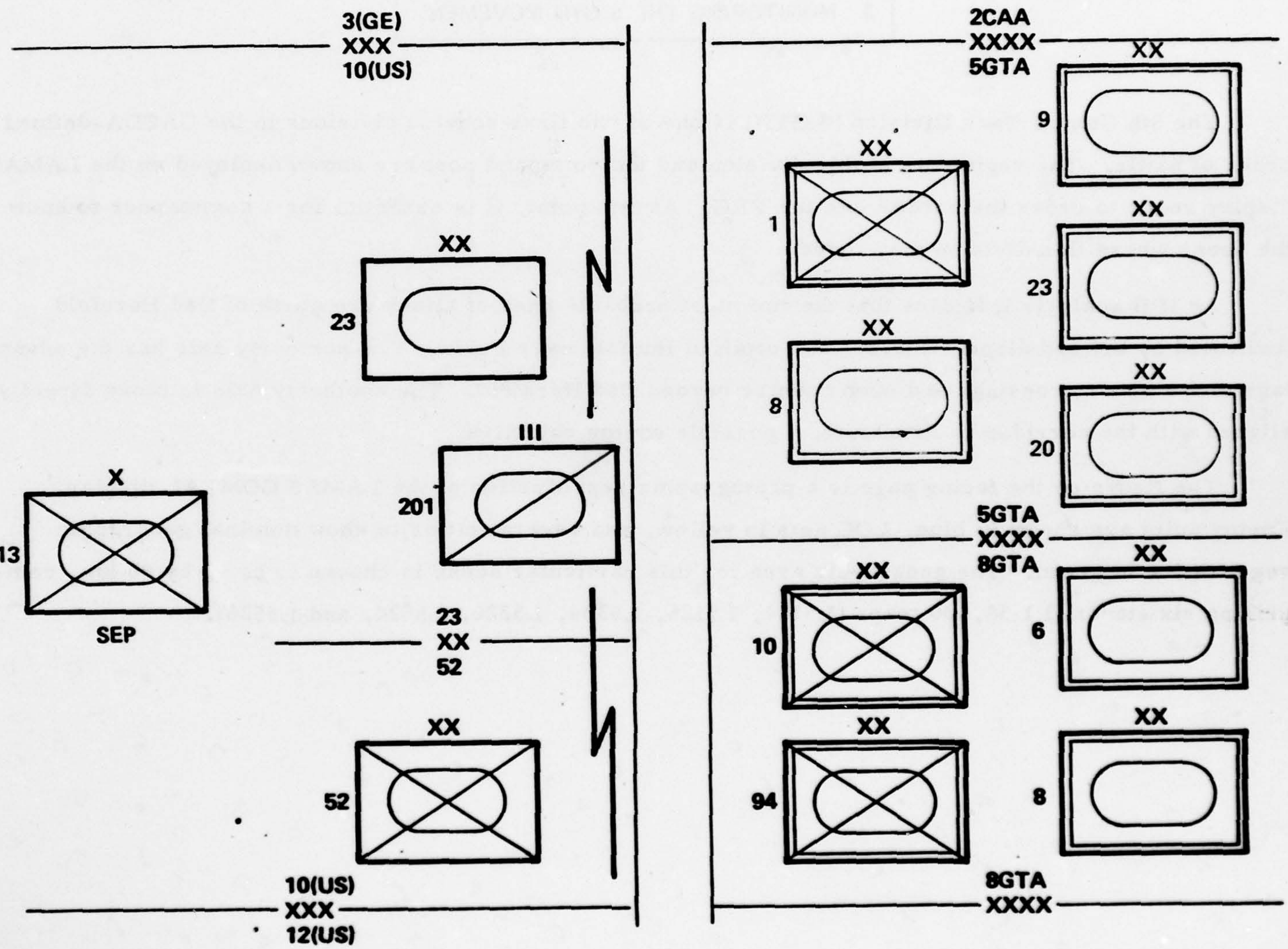

INTELLIGENCE
MESSAGES
PREPROCESS
REFORMAT
VALIDITY CHECK
ESTABLISH PRIORITIES
CORRELATE
FUSE
STORED TEMPLATES
TIME LATENESS
TIME-DISTANCE
DUPLICATION
MEASUREMENT BIAS
MOVEMENT DOCTRINE
LOC AND TERRAIN
UNIT ID AND
LOCATION TIME
HISTORIES
LAMAS
LOCATION AND
MOVEMENT ANALYSIS
SYSTEM
PROJECTIONS OF
FORCE BUILDUP/TIMING
FORCE CONSTITUTION
AXES OF ATTACK
INTEL COLLECTION REQ
INTERDICTION PLANNING
ALTERNATIVES
SENSITIVITIES

2. GROUND FORCE SCENARIO

The CACDA Command and General Staff College enemy order of battle in a Fulda Gap setting is used to evaluate LAMAS [Forward Deployed Force Operations – M3161/R3161(U)]. Two tank armies are defined. One, the 5th Guards Tank Army (5 GTA), is defined in detail down to the battalion level. The phase of combat selected for LAMAS is the road to war – the march of the 5 GTA from assembly (training) and staging areas to deployment at the initial line of contact.

The enemy forces that were modeled in LAMAS are shown in red. LAMAS operated on select units from the 5 GTA to study the movement of maneuver units down to the battalion level. The results are detailed in Section 3. LAMAS also operated separately on all 5 GTA maneuver units down to the regimental level and command posts down to the battalion level. This represents 25 regimental and five battalion-sized units. These results are detailed in Section 4. Finally, LAMAS operated on an augmented order of battle which included division-sized artillery units assigned by the front to aid in an initial breakthrough attempt. LAMAS was operated against numerous other scenarios to include the effects of logistics vehicles on LOCs, air defense unit movement constraints, and route interdiction.

ENEMY FORCES

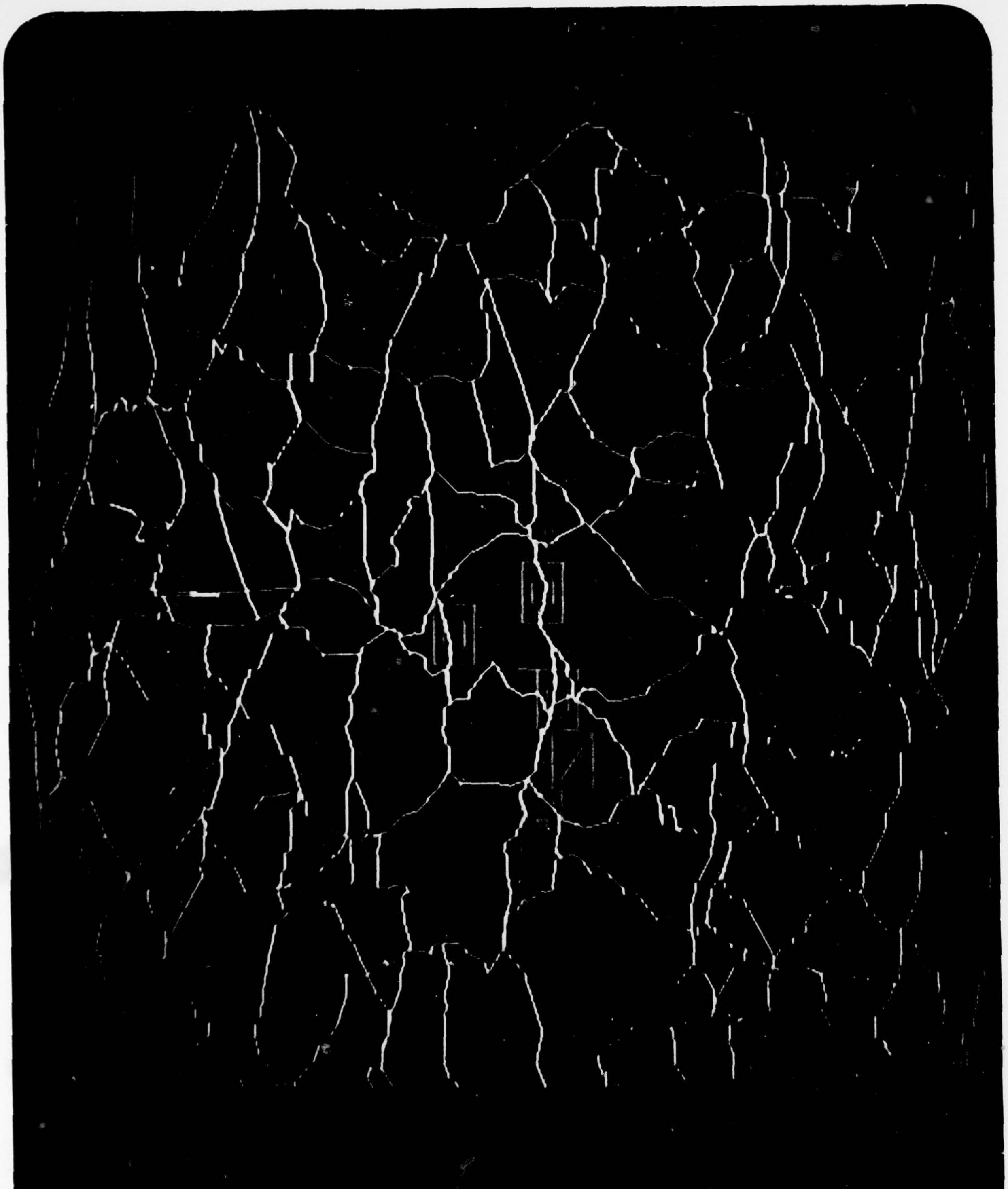


3. MONITORING THE 8 GTD MOVEMENT

The 8th Guards Tank Division (8 GTD) is one of two first-echelon divisions in the CACDA-defined order of battle. The regiments of this division and the command post are shown deployed on the LAMAS display ready to cross the border into the FRG. At this point, it is essential for a commander to know the areas where this division may move.

An IPB analysis indicates that the two most probable axes of attack are north of Bad Hersfeld (indicated by the red display cursor) and south of Hunfeld near Fulda. The northerly axis has the advantage of few river crossings and open country beyond Bad Hersfeld. The southerly axis is more directly aligned with the corridor to Frankfurt, a possible enemy objective.

The figure on the facing page is a photographic reproduction of the LAMAS COMTAL display. Enemy units are shown in blue, LOC nets in yellow, and several cities to show nominal geographic registration in green. The geographic area for this particular scene is chosen to be 45 by 66 km, comprising six standard 1:50,000 maps (L5124, L5126, L5324, L5326, L5524, and L5526).

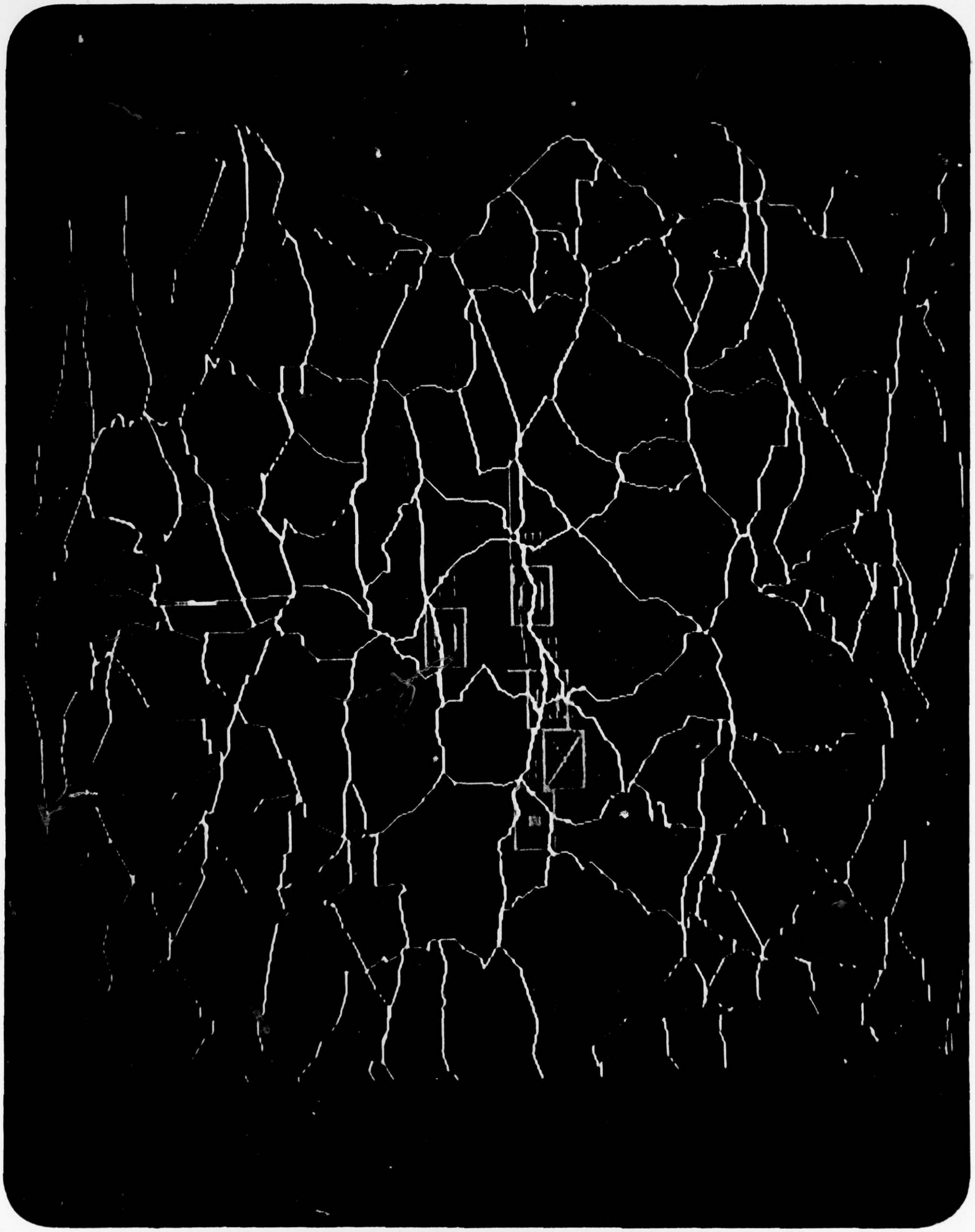


MOVEMENT PROJECTION TO THE NORTHERLY AXIS

It is currently mid-morning in Germany and the LAMAS analyst is projecting movement of the 8 GTD to start at noon. (The analyst will continue throughout the day to project movements reflecting changes in the time of day, weather, lighting, and tactical conditions.) The current weather is clear and the roads and terrain are dry. The enemy knows that our side is aware of his location.

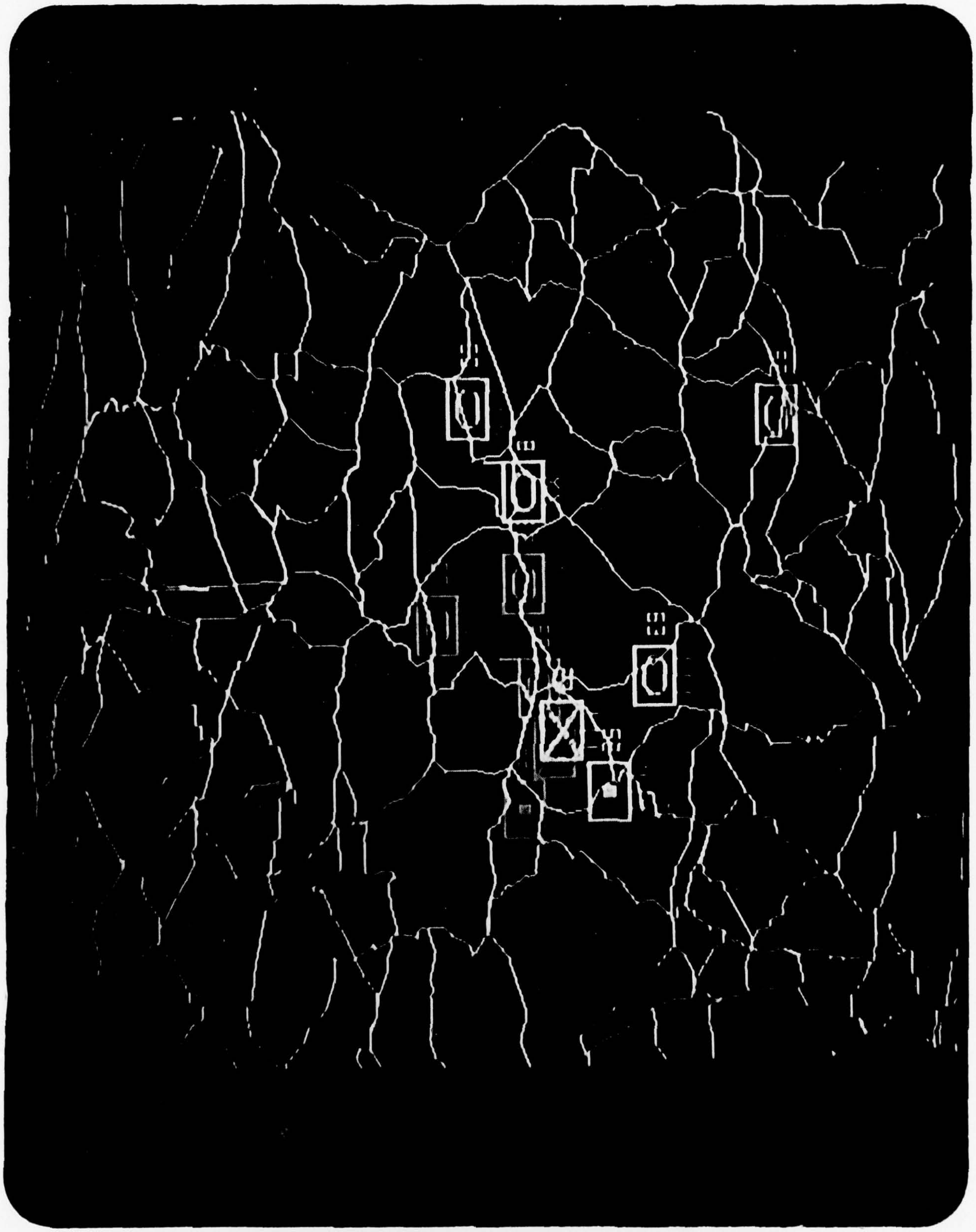
The LAMAS analyst has run the program by defining the northerly axis location and setting controls to indicate that the suspected enemy doctrinal movement will be with the maximum possible speed along least-risk paths. (As described later, this represents a 50-50 split between minimum-time and minimum-risk movement criteria.)

The paths are projected on the display as shown. The computer informs the analyst that the earliest a tank regiment can be deployed is 1 hour and 21 minutes and that the entire division deployment takes 2 hours and 38 minutes. An exception is the deployment of the artillery regiment which, because of its initial deployed position at the rear, takes 3 hours and 33 minutes. The analyst also notes that several units were forced to wait, indicating multiple unit intention for the same route segments. This suggests that there are preferred routes subject to possible interdiction.



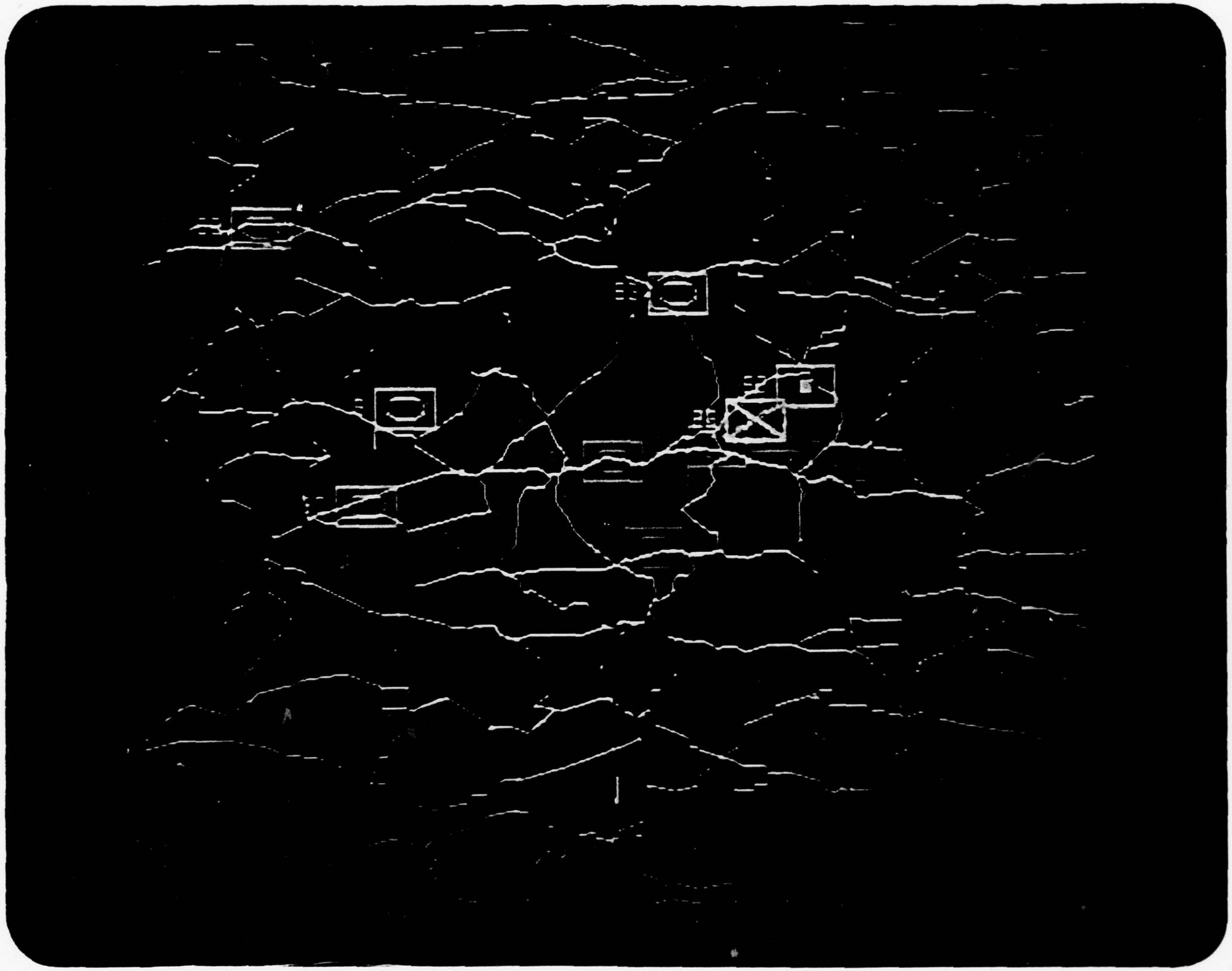
PROJECTED MOVEMENT SNAPSHOT AT 40 MINUTES

Forty minutes from the march command, the projected positions are displayed by the analyst. The 62 Tank Regiment is traveling northwest to lead the way. The 60 Tank Regiment and the division command post are traveling west and will later turn north. The other trailing units are jockeying their positions to follow the lead units.



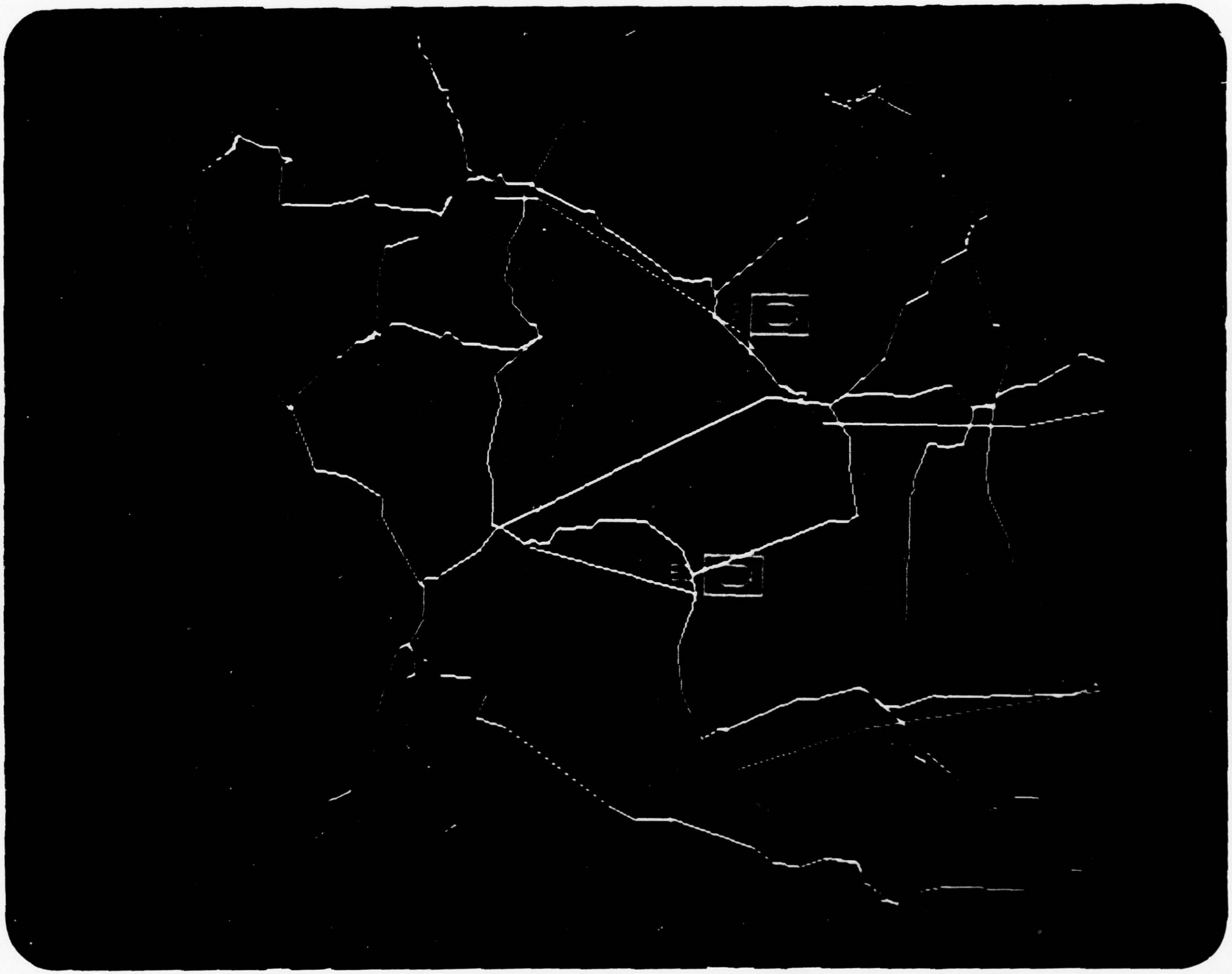
PROJECTED MOVEMENT SNAPSHOT AT 1 HOUR

One hour from the march command, the 62 Tank Regiment is near the expected final position, and the 60 Tank Regiment and division command post are beginning to move northward. At this point, the analyst chooses to expand the screen in the area of the 60 Tank Regiment to investigate in detail why the units have selected these routes, to investigate march path vulnerabilities, and to plan for recce tasking.



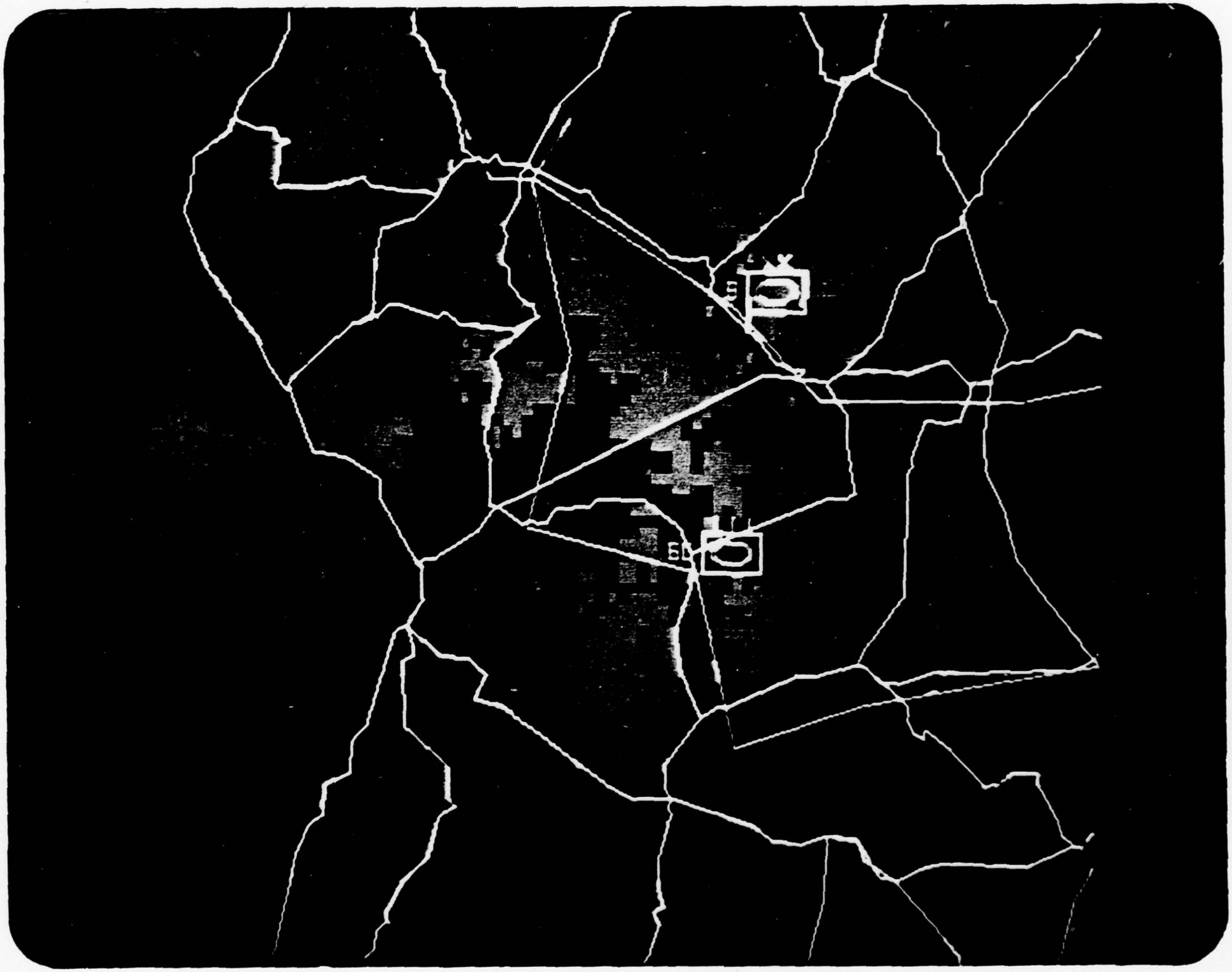
ZOOM TO SELECTED AREA

Zooming the screen to cover a 20 by 20 km area at 1 hour from the possible march command shows units and routes on an uncluttered screen. The route for the division command post is the Rasdorf to Eiterfeld second-class road. The route for the 60 Tank Regiment begins at Spahl to Mittelaschenbach along a narrow light surface road, continues to Kirchhasel along a main road, and breaks north to Eiterfeld along a second-class road. Road classes are determined by displaying the data base elements. The towns and villages are determined by matching the LAMAS display with the 1:50,000 scale maps (see Section 7).



THE CROSS-COUNTRY MOVEMENT OVERLAY

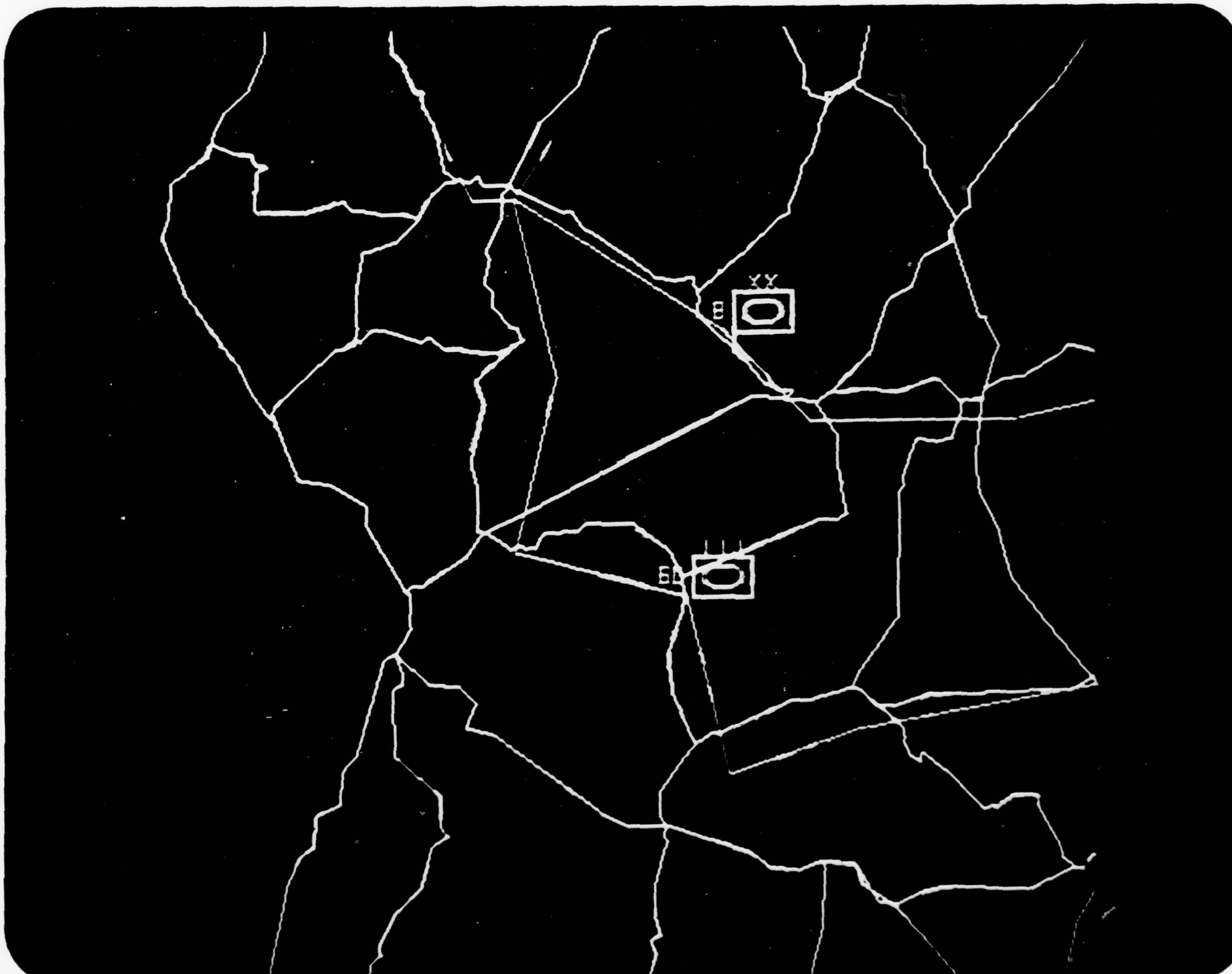
Calling for the cross-country trafficability overlay from the computer file enables the LAMAS analyst to determine how constrained the enemy is to moving off road. (The overlay color code is described later in Section 5.) Bright red indicates that only very limited tracked vehicle movement is possible. The command post is traveling a path that allows for freedom to move off road; the tank regiment, however, travels through several areas of limited off-road movement, particularly on the northerly leg toward Eiterfeld. This is a possible area to interdict or to mine.



THE AIR CONCEALMENT OVERLAY (JULY)

The analyst is interested in learning what concealment from air observation the forestation may provide the enemy during march. (The overlay color code is described later in Section 5.) Bright green indicates nearly complete cover. The command post is traveling in the open and cannot easily seek natural concealment. The tank regiment has some cover on its path, but it would be difficult to rapidly conceal the entire unit. These overlay data are for July.

The analyst will choose to task air recce along the routes between Rasdorf and Eiterfeld, between Spahl and Mittelaschenbach, and in the area of Kirchhasel (all relatively open areas) between 45 and 90 minutes after the postulated march command.

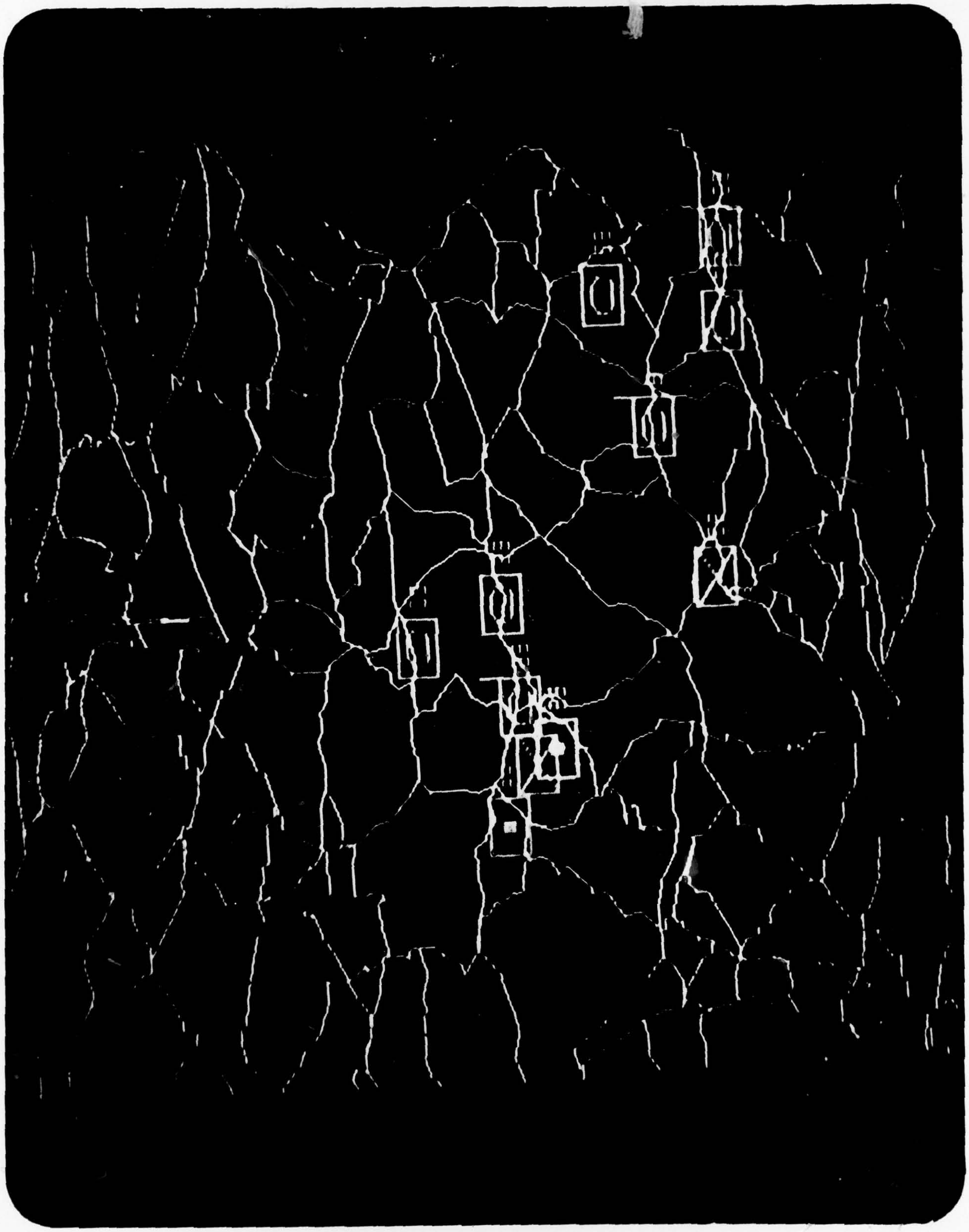


THE AIR CONEALMENT OVERLAY (DECEMBER)

The air concealment overlay for winter is considerably less than for summer in this European region. This is due to the predominance of deciduous foliage. Other areas show little difference between months where the forest is predominantly coniferous.

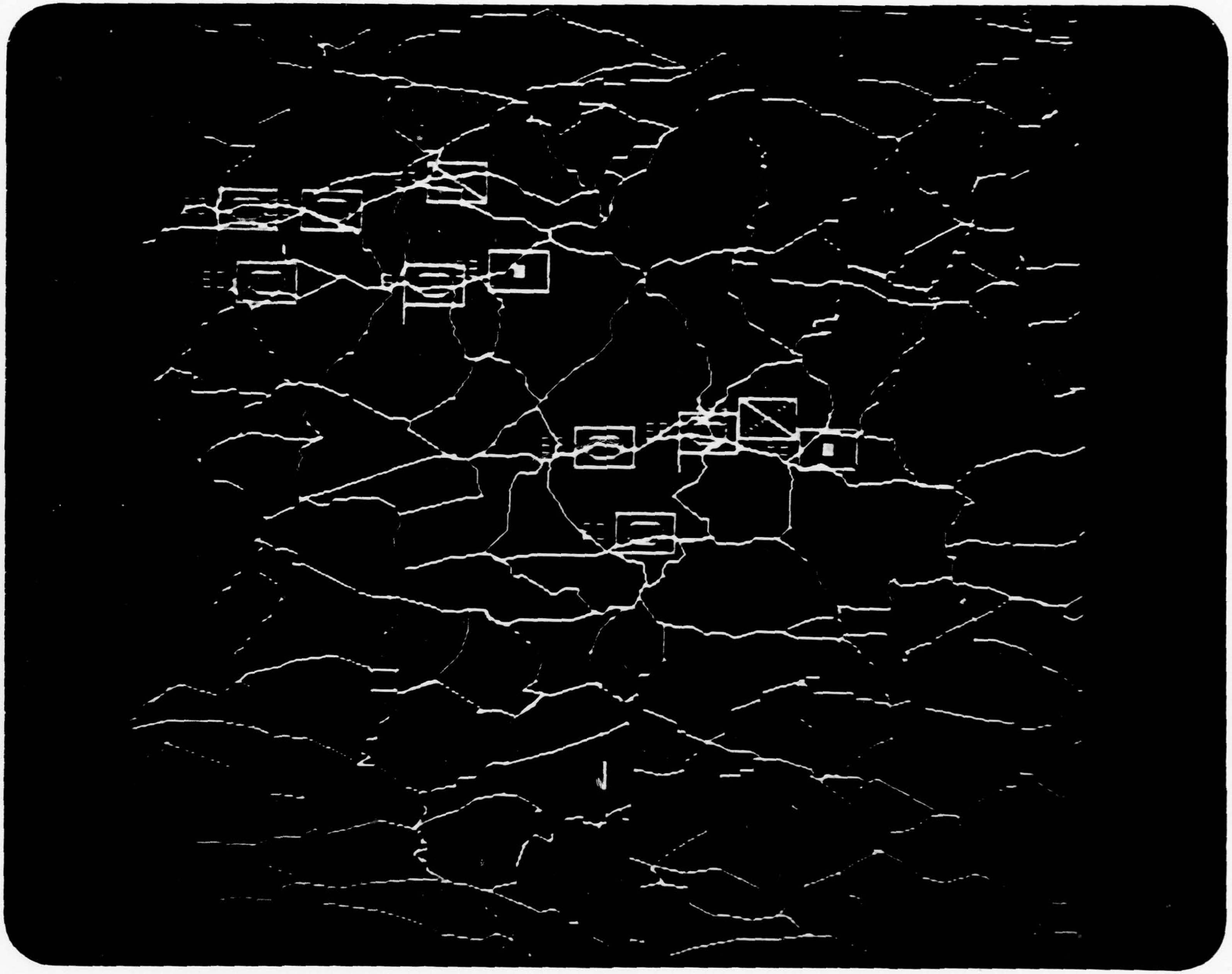
PROJECTED MOVEMENT SNAPSHOT AT 2 HOURS AND 30 MINUTES

Recalling the original map scale, the analyst displays the units at 2 hours and 30 minutes. The rifle regiment is traveling from Vacha to Friedewald along a primary road, the identical route of the 62 and 63 Tank Regiments. This is a highly preferred route because of good trafficability, good off-road movement capability, and some concealment from air observation. Because of multiple units contending for this route, the rifle regiment has had to wait its turn. The computer program automatically determined that this was better than finding an alternate route.



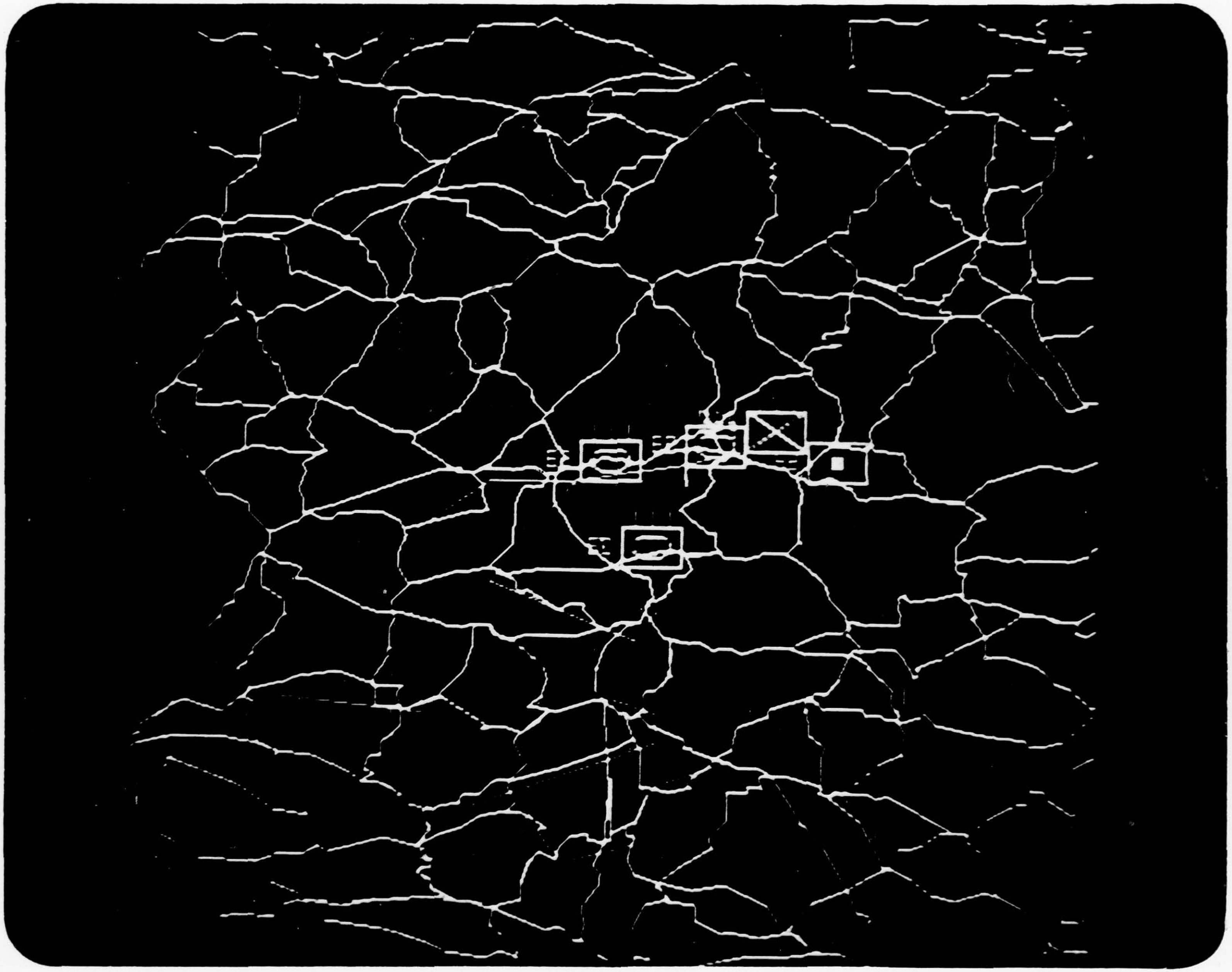
FINAL DEPLOYMENT

All units of the division are deployed 3 hours and 33 minutes from the beginning of the march command. This formation reflects one possible enemy deployment according to doctrine.



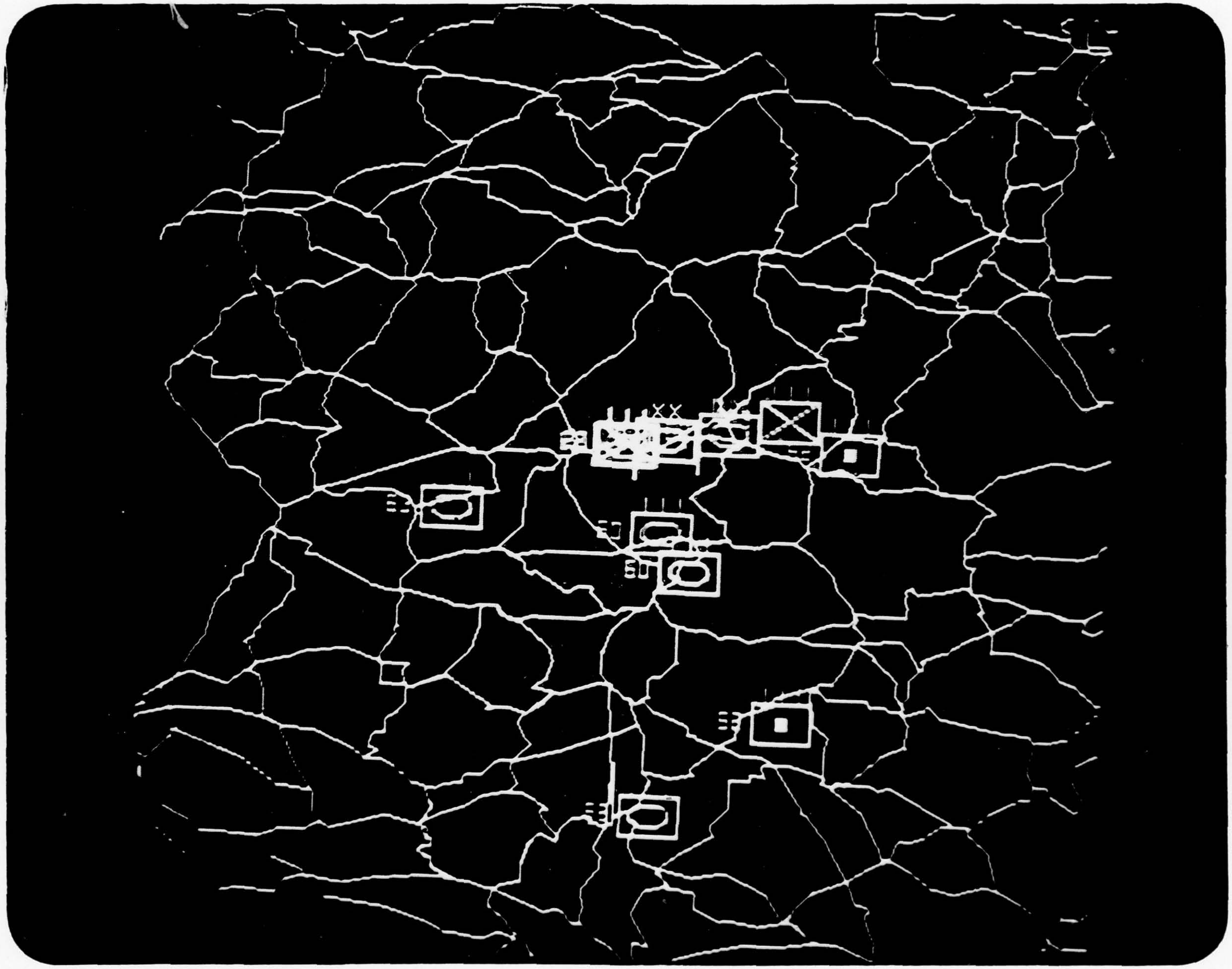
MOVEMENT PROJECTION TO THE SOUTHERLY AXIS

A second probable axis of attack is to the south. The LAMAS analyst has run the program using the same conditions as before to compare results. The computer informs the analyst that the earliest a tank regiment can be deployed is 2 hours and 3 minutes or 42 minutes slower than if the division moved to the northerly axis. The entire division can be deployed in 3 hours and 49 minutes. Like movement to the north, the artillery is deployed late at 3 hours and 14 minutes.



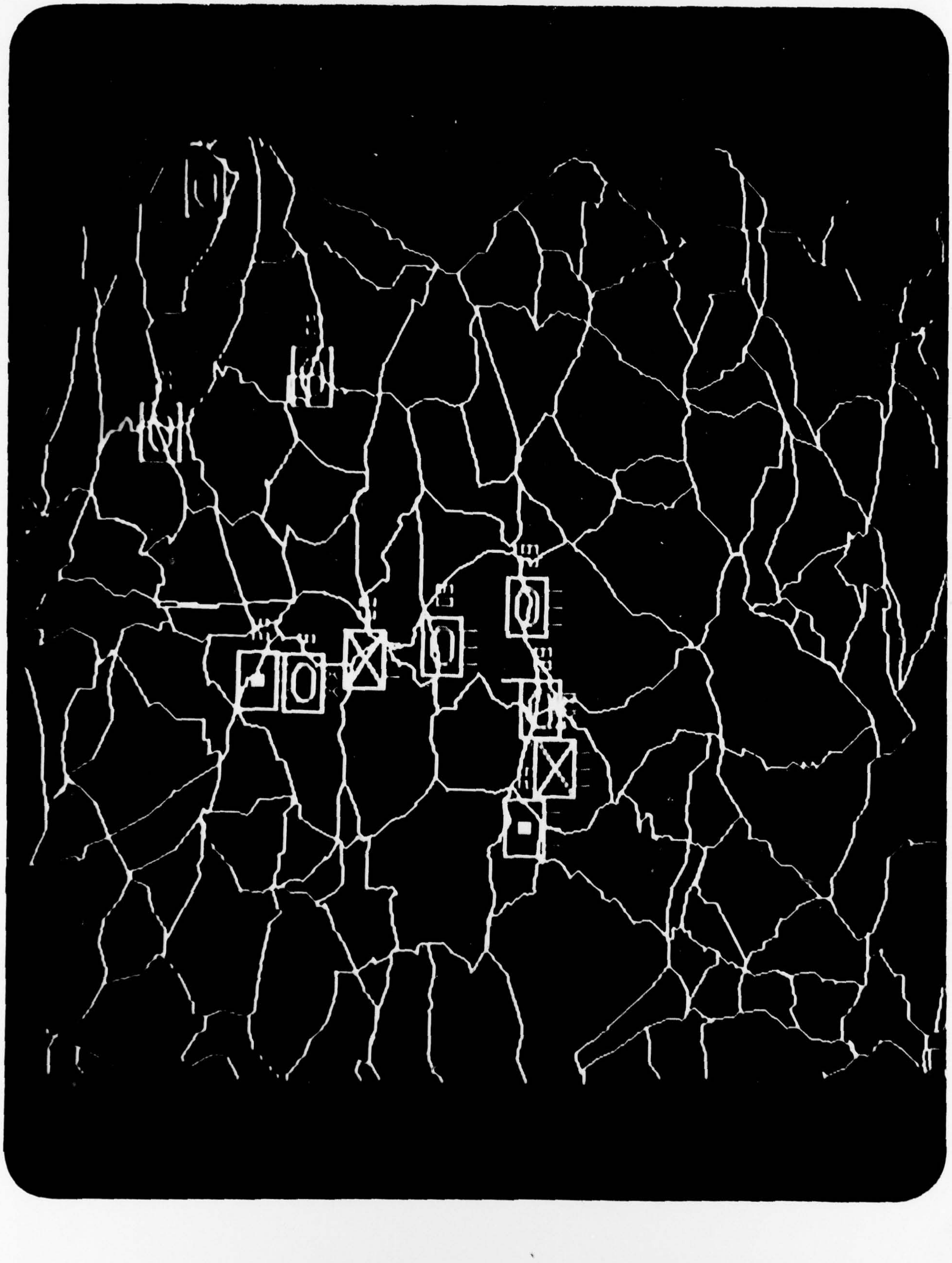
PROJECTED MOVEMENT SNAPSHOT AT 1 HOUR

One hour from the march command, the units have broken to the south, except for the command post and the rifle regiment. These units are waiting for the columns preceding them to pass and for routes to clear.



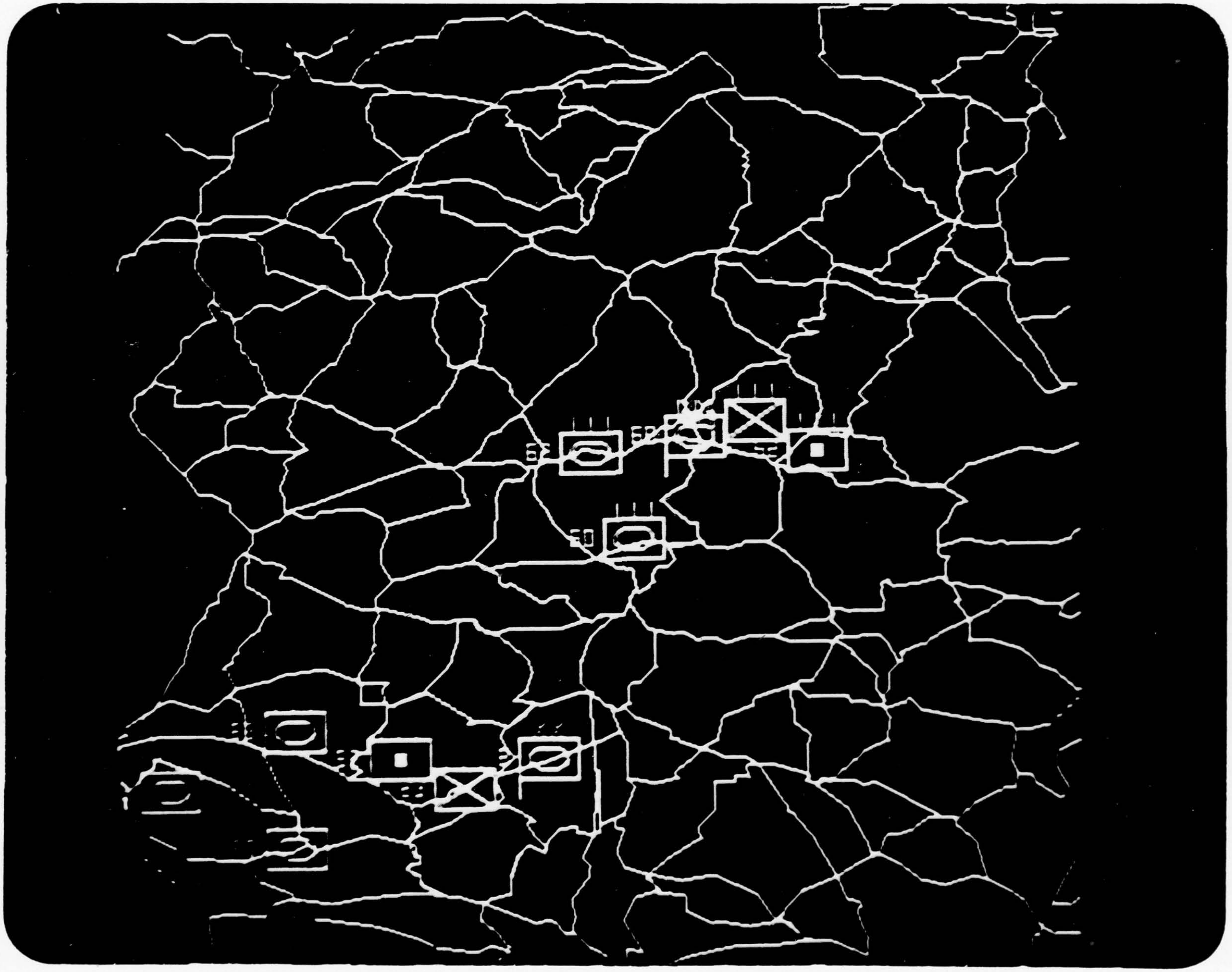
PROJECTED MOVEMENT SNAPSHOT AT 2 HOURS

At 2 hours, the lead units are nearly in position. Because the lead units are still marching, the rearward units must slow their approach as they demand the same paths.



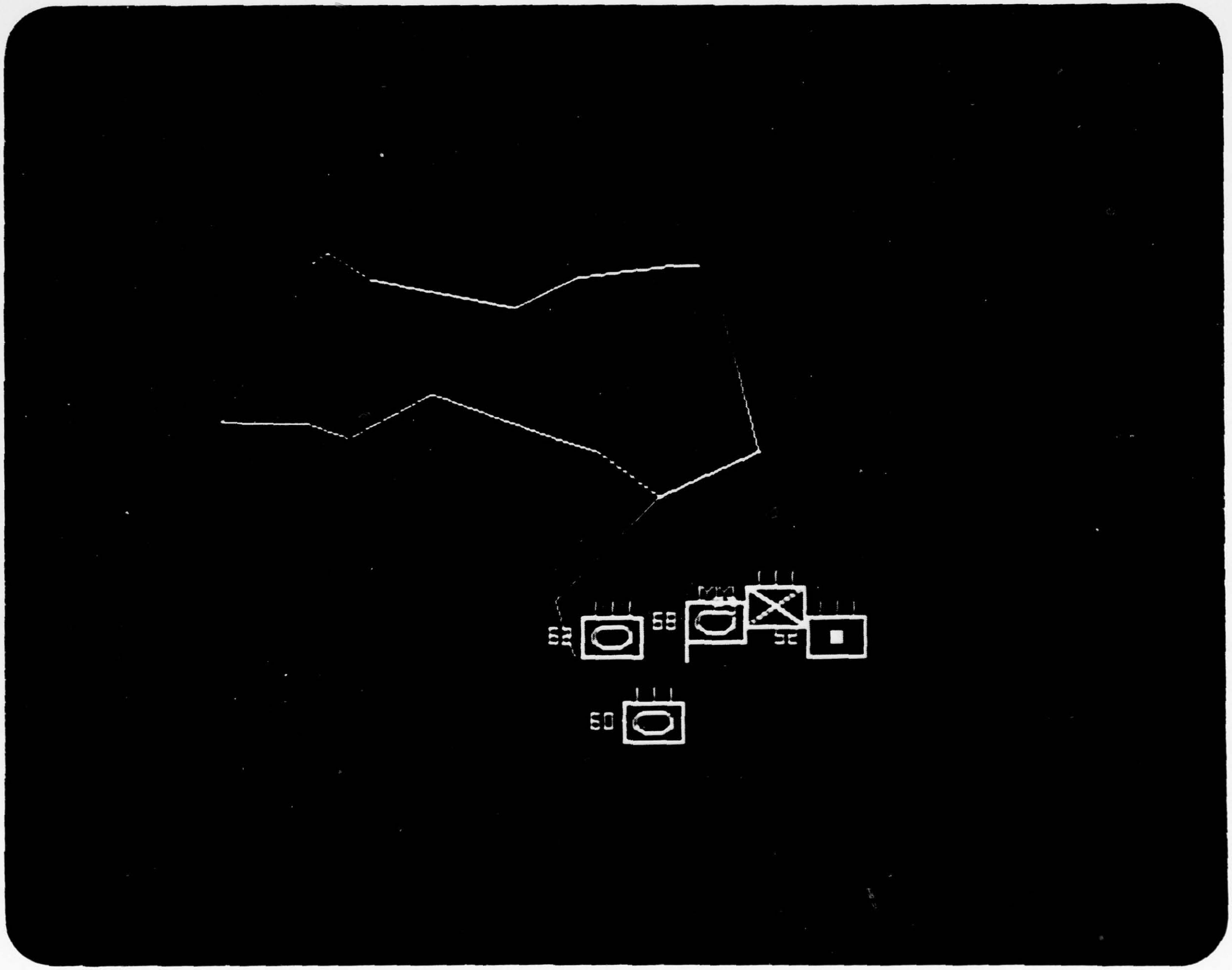
FINAL PROJECTED DEPLOYMENT

At 3 hours and 49 minutes, the division is deployed. The formation is doctrinally similar to the formation at the possible northerly axis.



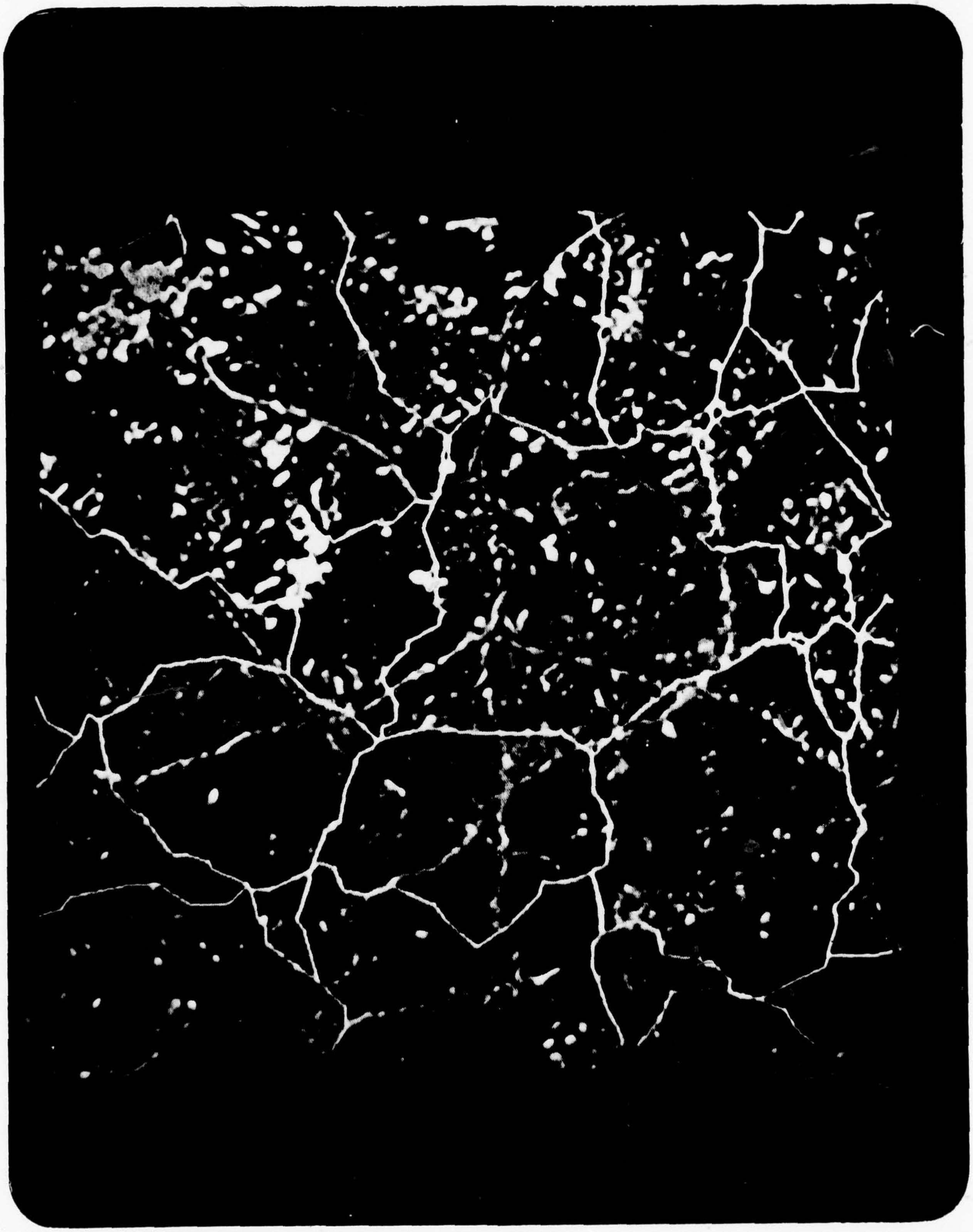
INTERDICTION PLANNING

The LAMAS operator is searching for the best interdiction locations. For the projected march to the northerly axis, he requests the program to find the optimum time and location to interdict to slow the march. The computer informs him of the three best times and locations. The best interdiction will slow the march by 118 minutes, doubling the march time. The analyst rejects this alternative, however, because it requires interdiction at the current enemy unit locations immediately. Instead, he selects the second best interdiction scheduled between 20 and 40 minutes after the postulated march command. This will delay the march by a minimum of 68 minutes, if accomplished. The display shows the uninterdicted path of the 62 Tank Regiment in green and the best route the enemy can select after interdiction in pink.



LANDSAT IMAGERY OVERLAY

As an experiment, a sample LANDSAT satellite photograph was overlaid on the display. This image is not of the Fulda Gap region, but rather of a region in Colorado. We are currently working to overlay higher-resolution photographs of the Fulda Gap area.

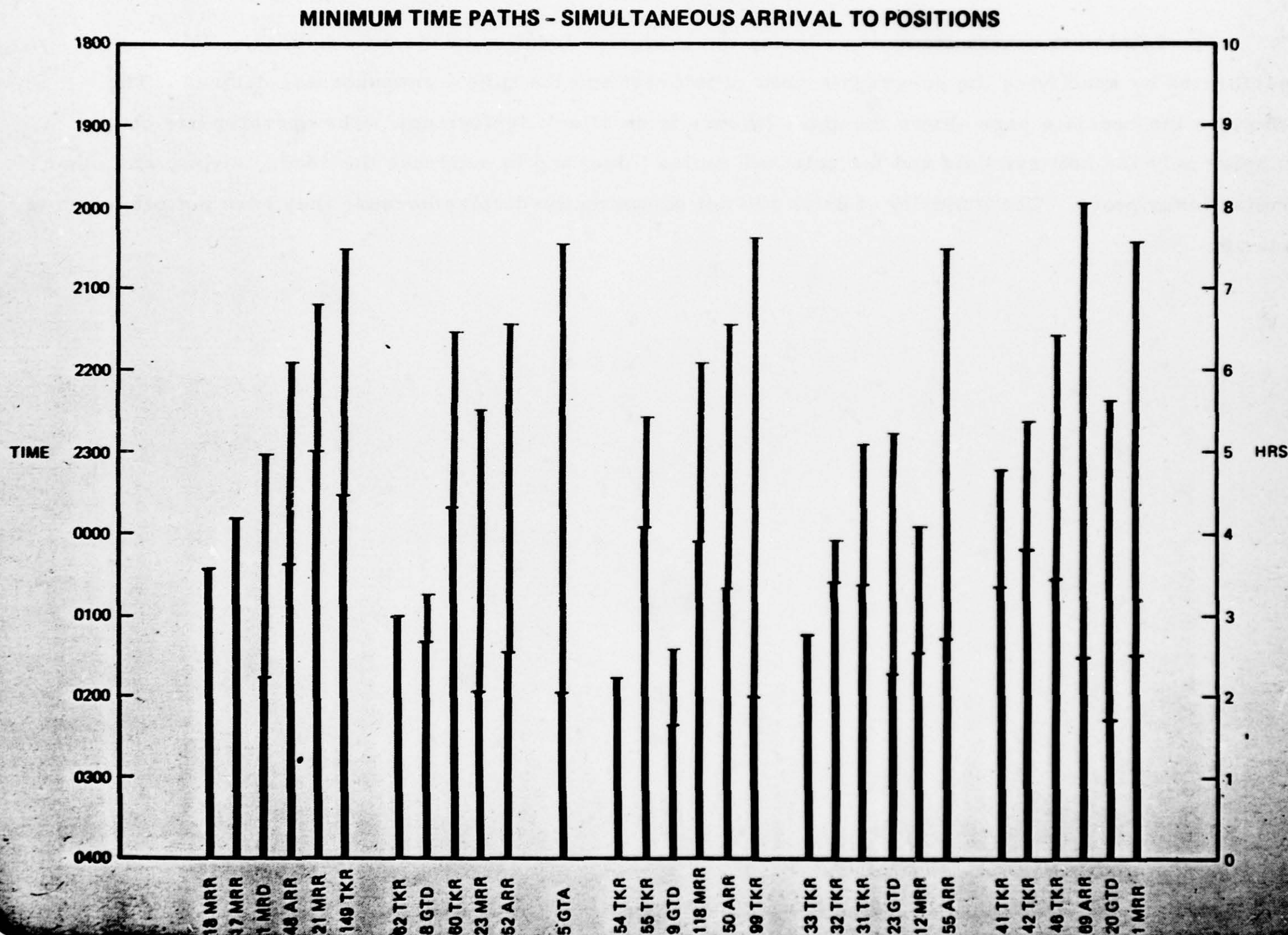


4. MARCH OF THE 5 GTA

LAMAS showed that most of the regiments of the 5 GTA would be subject to delay (waiting times are shown in red on the diagram) while marching unopposed to initial contact. The cause of this is as before — multiple contention between several units for identical LOCs. The move algorithm in LAMAS again found that while operating under the enemy minimum march time doctrine it was best for lower-priority units to wait until highly trafficable LOCs became clear, rather than to traverse over a poor LOC that was always clear.

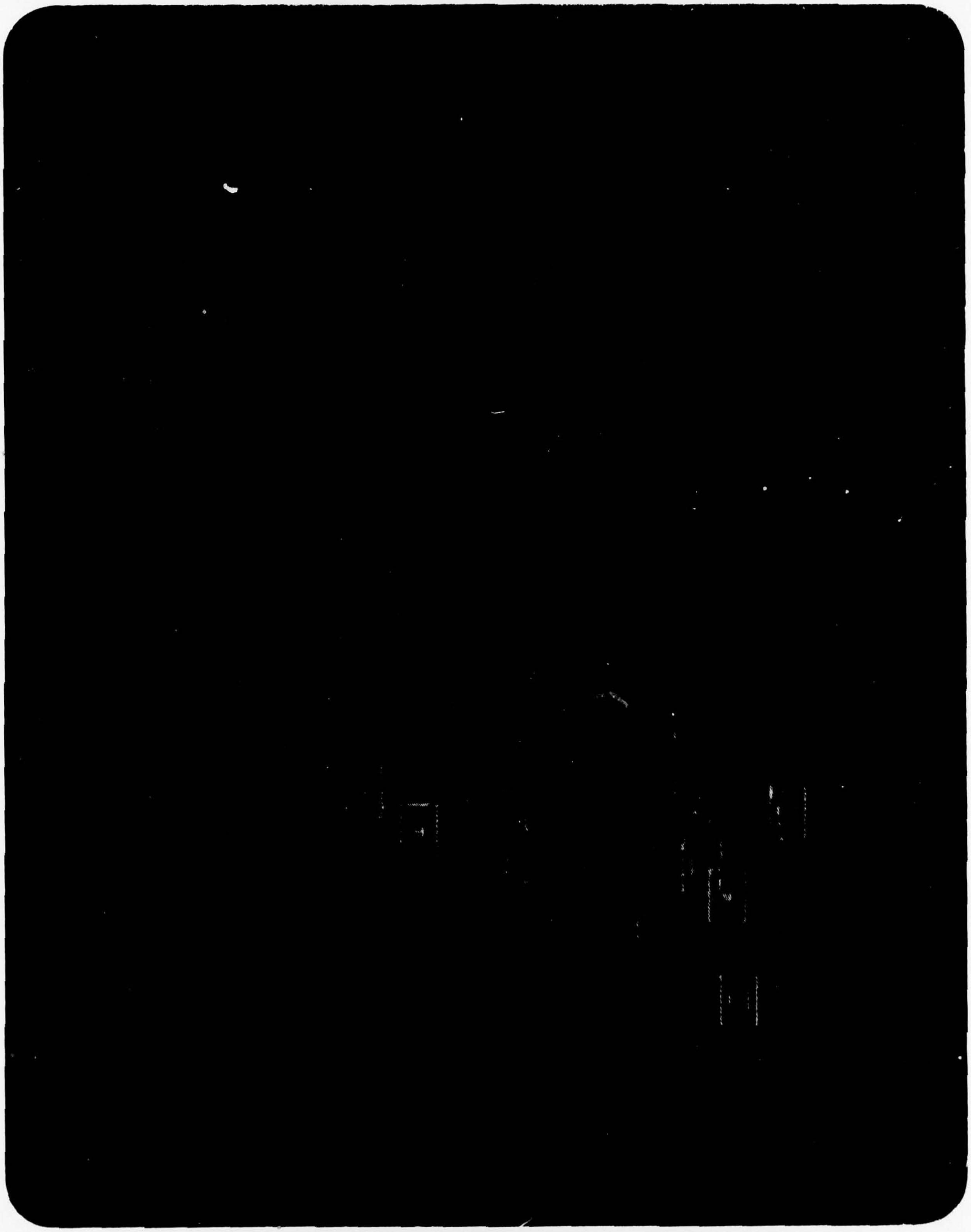
LAMAS also showed that the first regiments would begin movement at 2000 or about 8 hours prior to the postulated attack deployment time of 0400. This time reflects the close control required to bring about the simultaneous arrival of units to their deployed positions, a condition assumed for this march. When simultaneous arrival is not assumed, unit movement can begin 1 to 2 hours later, shortening the march times and adding to the element of surprise. This shows an interesting tradeoff of doctrine the enemy must make: Is massing for attack across a broad front advantageous or is a surprise attack along a limited axis better? The weather conditions used by LAMAS in generating these data were overcast with dry LOCs and terrain.

5 GTA MARCH TIMES FROM TRAINING AREAS TO COMBAT POSITIONS



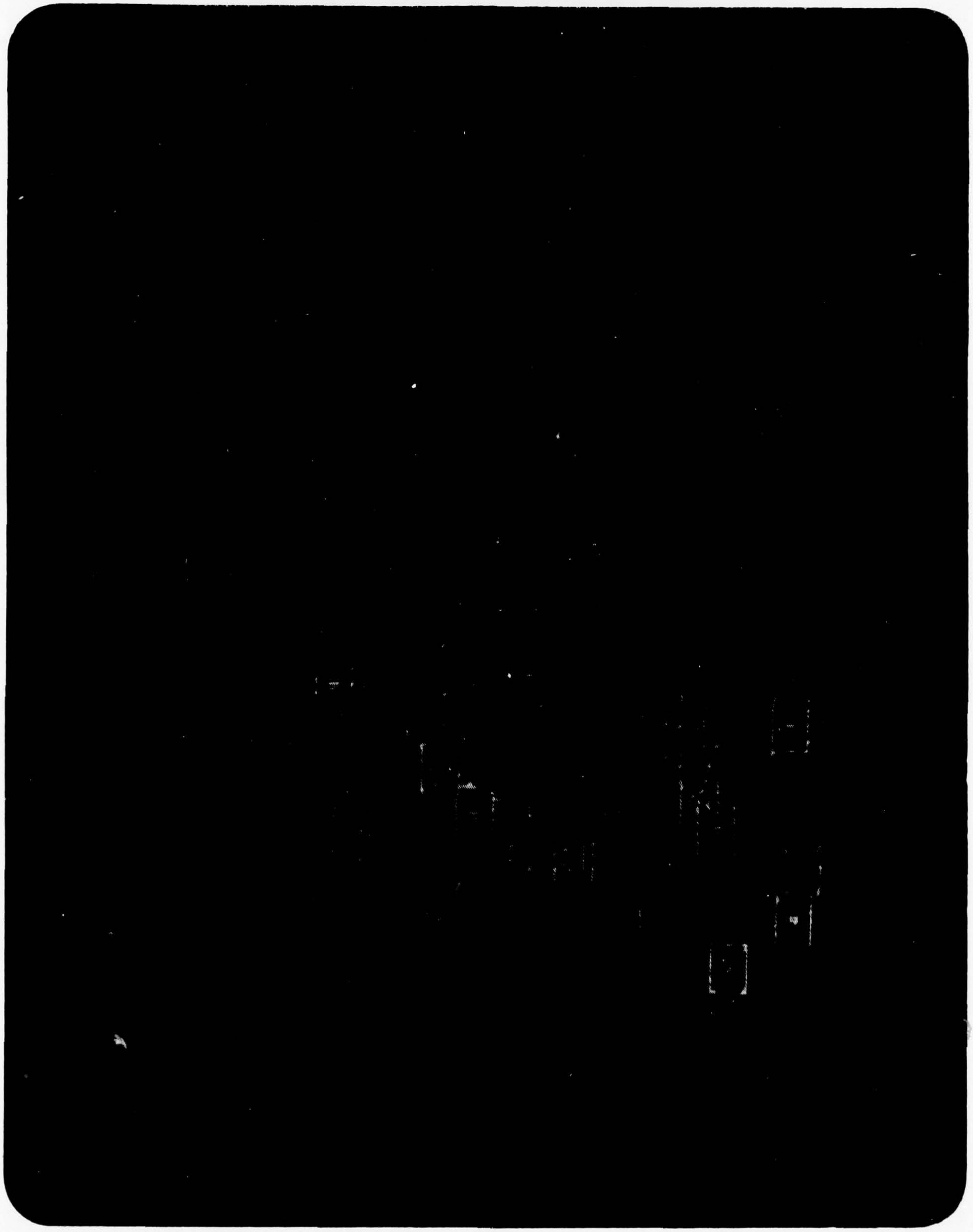
MINIMUM-TIME MARCH OF THE 5 GTA

The LAMAS operator elected to display the projected location of the 5 GTA units. This was performed by specifying the geographic area of interest and the time a snapshot was desired. The photo on the opposite page shows the units 7 hours from attack deployment. The operator has chosen to display only the unit symbols and the selected routes (blue) and to suppress the roads, cities, and other relief descriptors. The majority of units are not shown on the display because they have not yet begun to march.



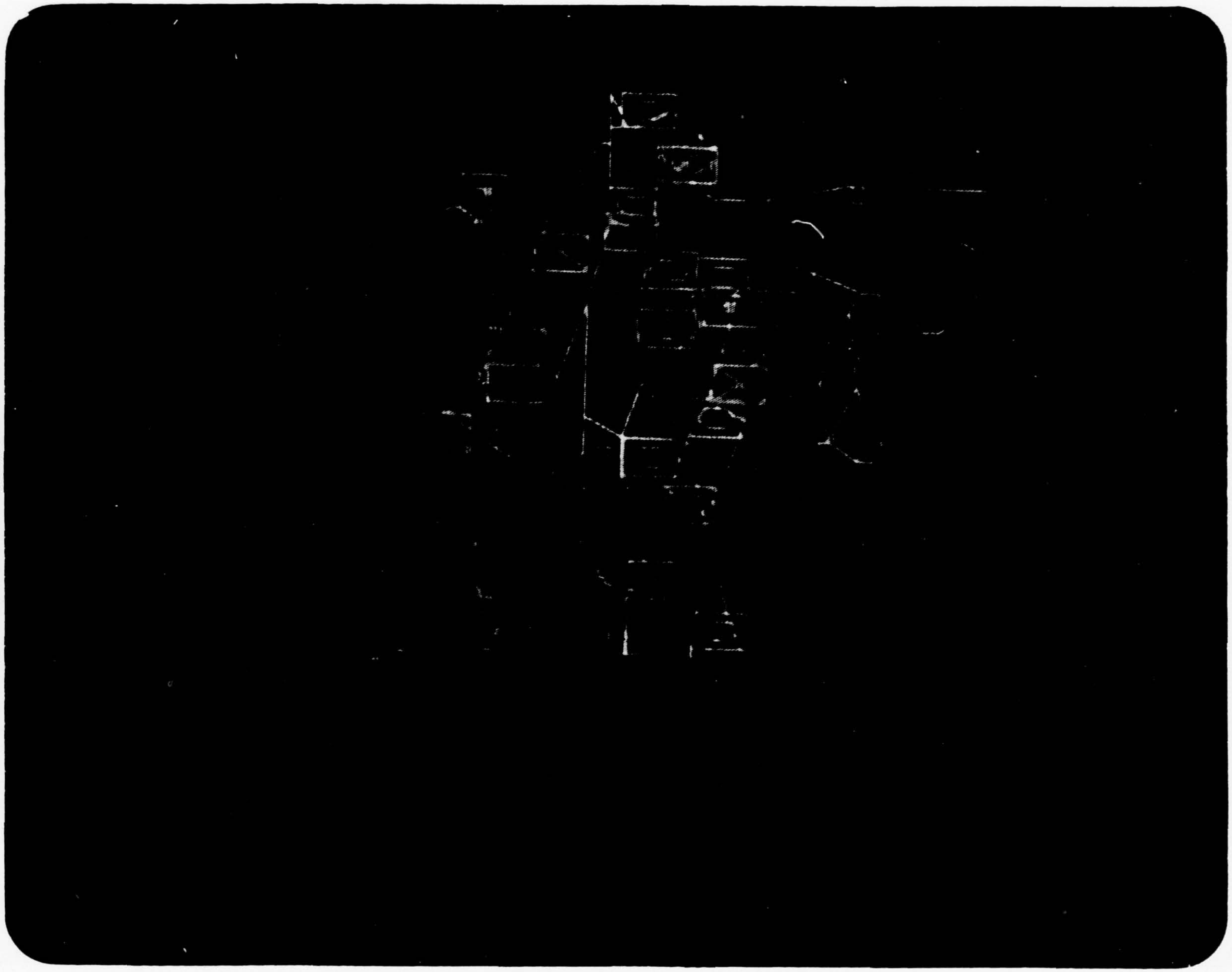
MARCH OF THE 5 GTA – 4 HOURS FROM ATTACK DEPLOYMENT

At 4 hours from attack, lead units have moved out from their assembly areas and other units are following. At this time most, but not all, units have begun the march.



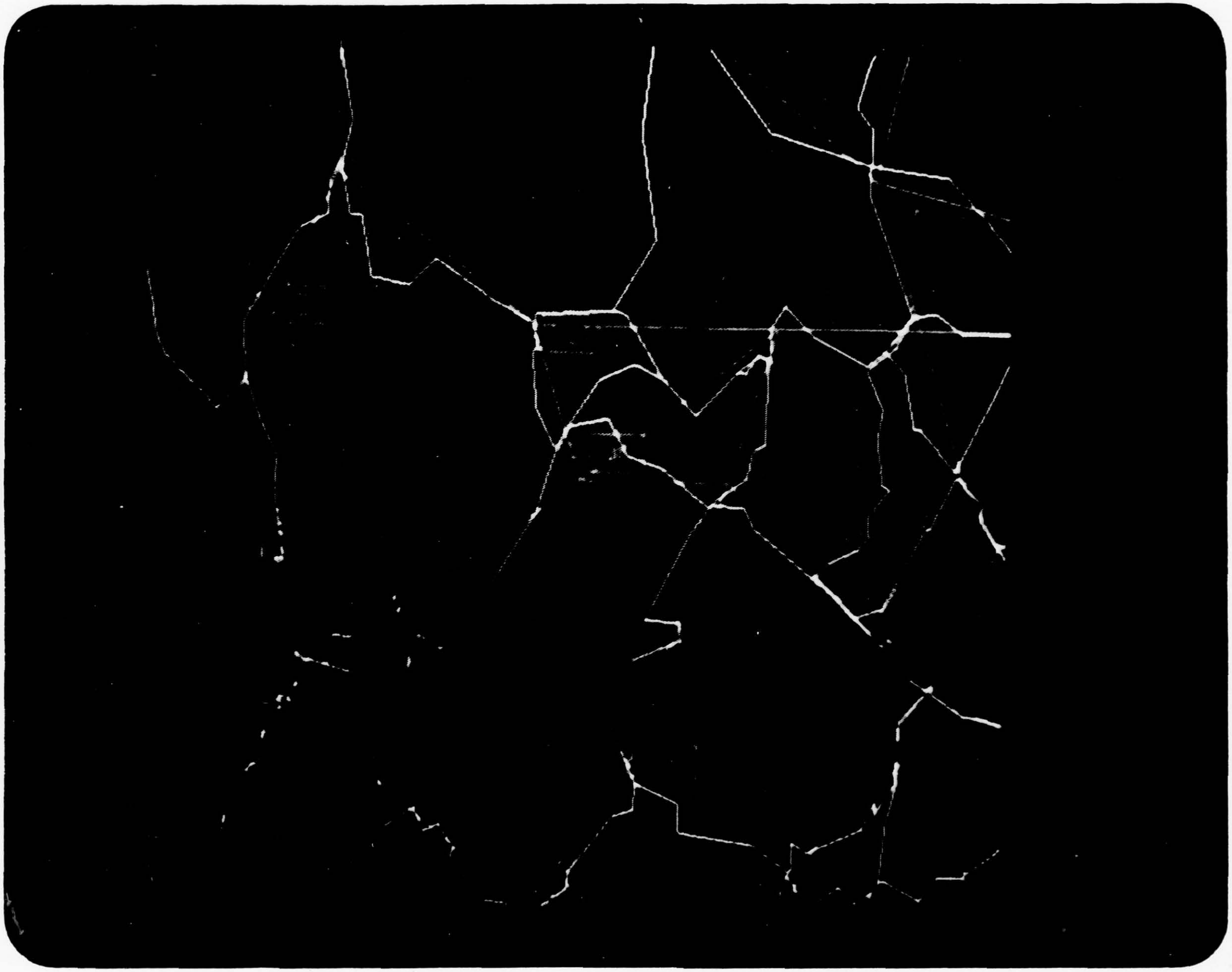
MARCH OF THE 5 GTA – ATTACK DEPLOYMENT

The attack deployment of the army is shown here. In the upper left, the 1st Motorized Rifle Division (MRD) is spread across a relatively wide front. The regimental units belonging to this division include the 17th, 18th, and 21st Motorized Rifle Regiments (MRRs), the 149th Tank Regiment (TKR), and the 4th Artillery Regiment (ARR). At the lower left is the 8th Guards Tank Division (GTD) concentrated together. (This division is analyzed in Section 3 starting with this deployment and projecting ahead.) To the right are three second-echelon divisions (the 9 GTD, the 23 GTD, and the 20 GTD).



DETAIL OF THE 23 GTD

The operator has elected to zoom in to investigate the projected march details of the 23 GTD. Because fewer units are visible, the operator has chosen to show the LOCs (yellow), but omits the relief (towns). Coincidently, the 5 GTA headquarters unit is marching in the same area.

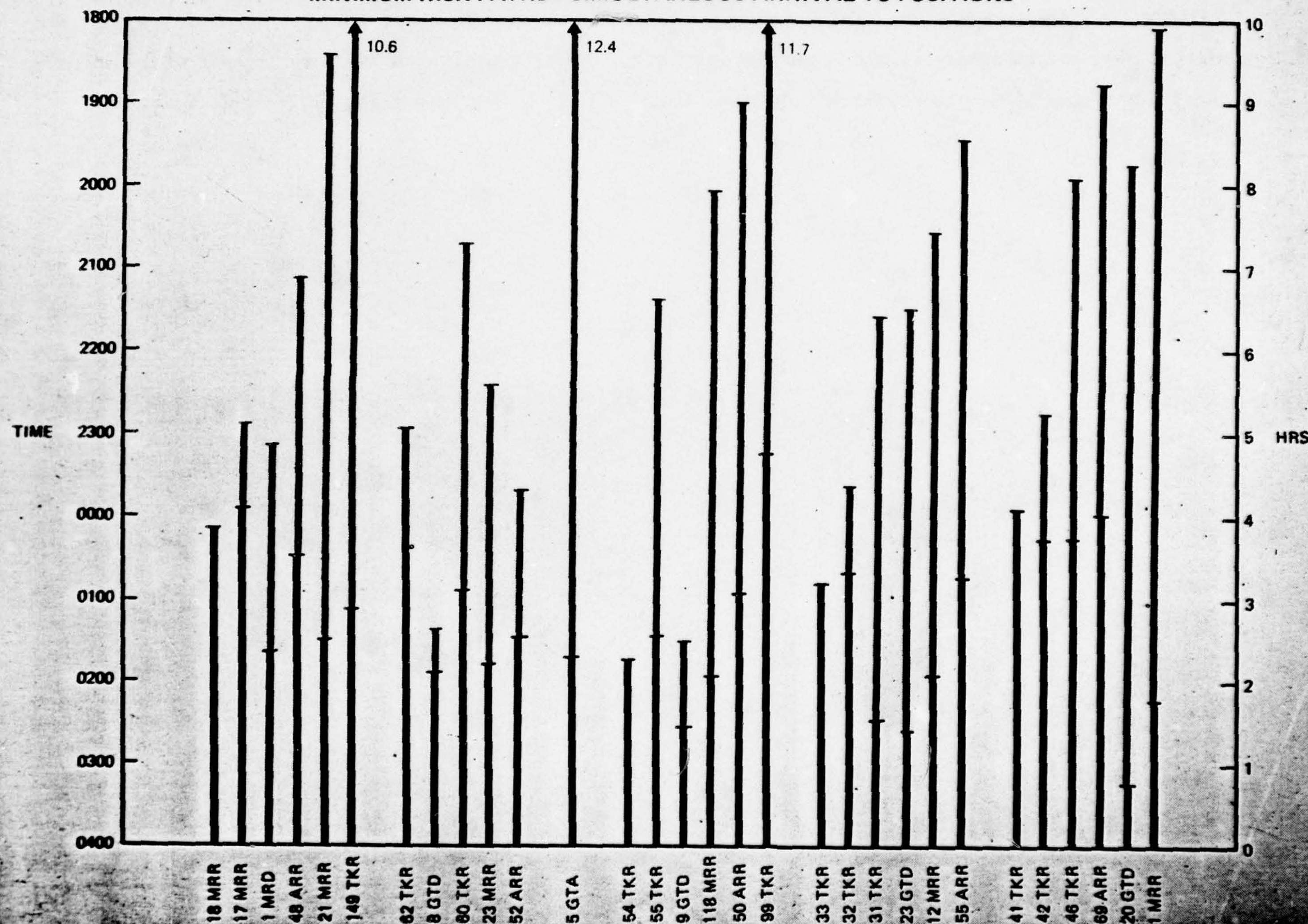


MINIMUM-RISK MARCH OF THE 5 GTA

LAMAS showed what the march time penalty would be if the enemy elected to travel minimum-risk routes rather than minimum-time routes. Comparing the march times shown in this diagram with the minimum-time route march times indicates a 1- to 3-hour penalty, except for several units able to travel the routes in the same time. The longer minimum-risk march times occur because of a strong preference for certain safe roads (e.g., no bridges) by numerous units. Often there is a long queue of maneuver units at road intersections making heavy demands for select minimum-risk roads. This phenomenon shows another tradeoff in doctrine the enemy must make: Is movement minimizing risk advantageous or is maximizing speed better?

5 GTA MARCH TIMES FROM TRAINING AREAS TO COMBAT POSITIONS

MINIMUM RISK PATHS - SIMULTANEOUS ARRIVAL TO POSITIONS



5 GTA MOVEMENT TO BORDER – SIMULTANEOUS MARCH COMMANDS

Using LAMAS to move the 5 GTA and start the units on the same march command shows that the regimental presentation rate is six deployed per hour. This is equivalent to a move rate of the entire 5 GTA of 8 km/hr. A daytime march command time of 1200 hours was selected for this march.

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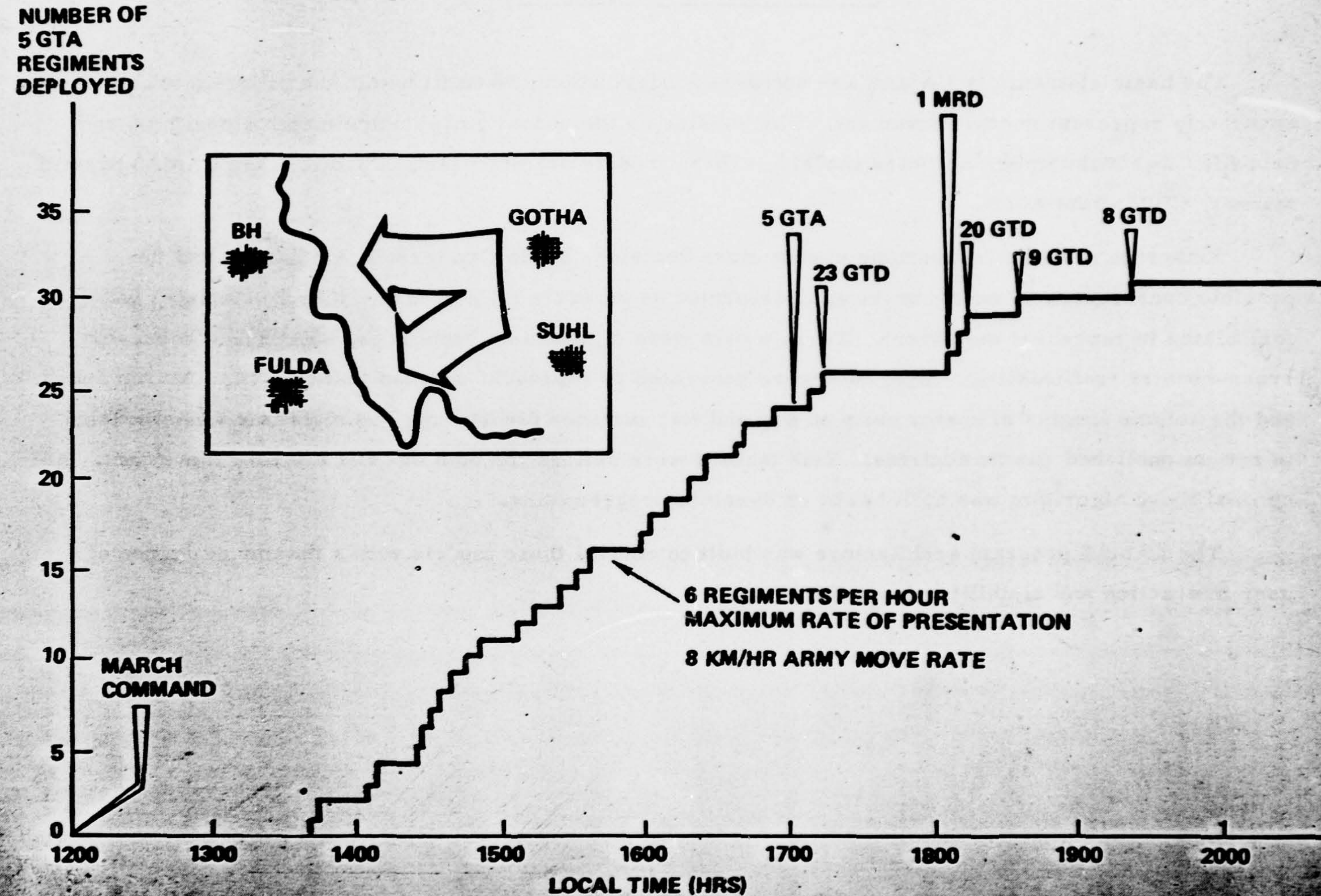
5 GTA MOVEMENT TO BORDER

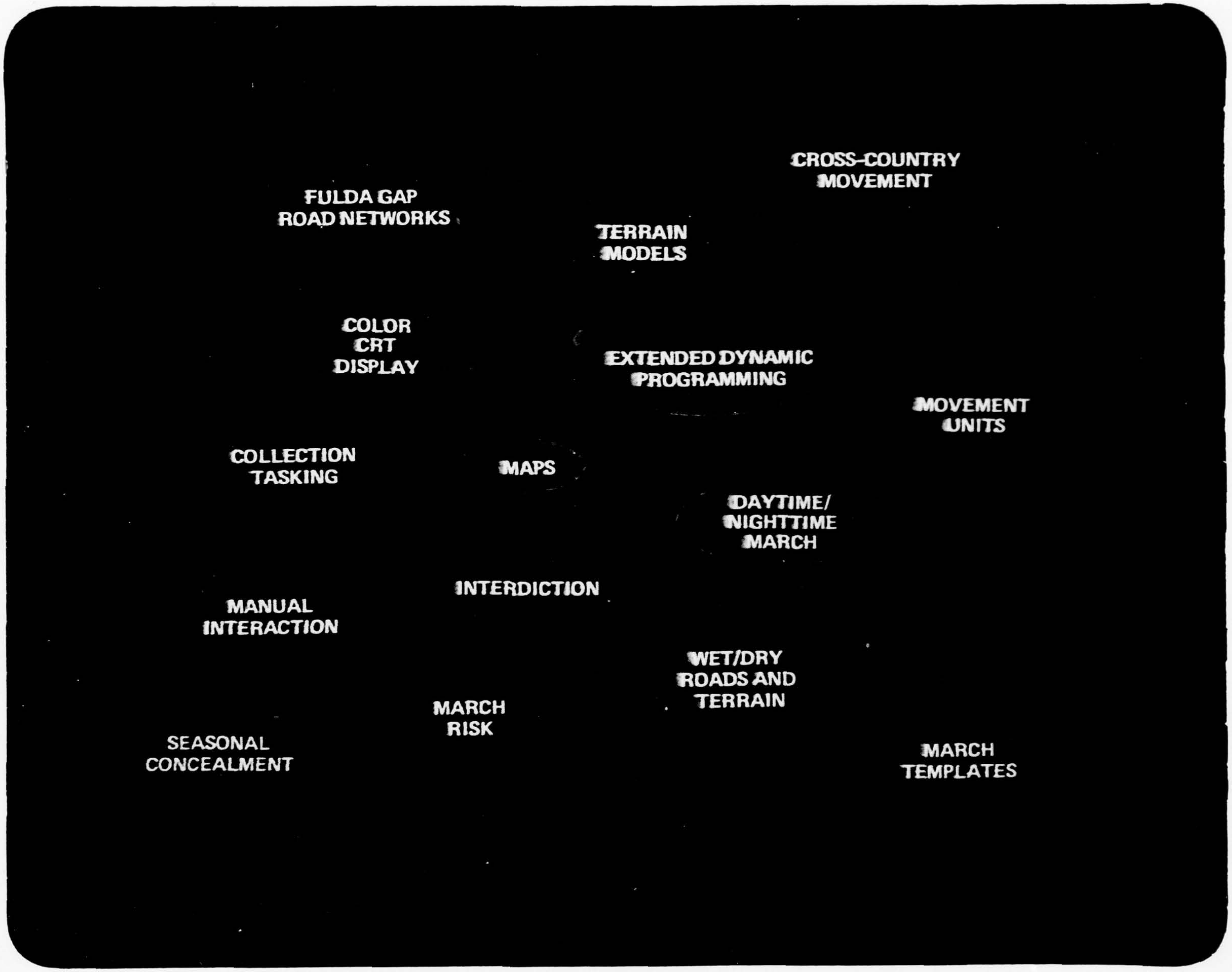


5. LAMAS SOFTWARE MODELS

The basic elements in LAMAS are software models which, when fit within the program architecture, accurately represent enemy movement. The bubbles on the opposite page name major algorithms and data files that make up the software models. These models are discussed in detail in the LAMAS System Manual, CDRL Item A00B.

Extensive research concerning enemy move doctrine, Fulda Gap terrain and LOCs, and the possible constituency of enemy units was performed as an early LAMAS task. March templates were formulated to represent movement. Terrain data were digitized as supplied by USAETL to represent cross-country trafficability. LOC data were generated to represent on-road trafficability. March speeds and the column lengths of enemy units on dry and wet surfaces for daytime and nighttime were modeled to reflect published enemy doctrine. Risk factors were defined for both on- and off-road movement. An optimal move algorithm was built based on dynamic programming.

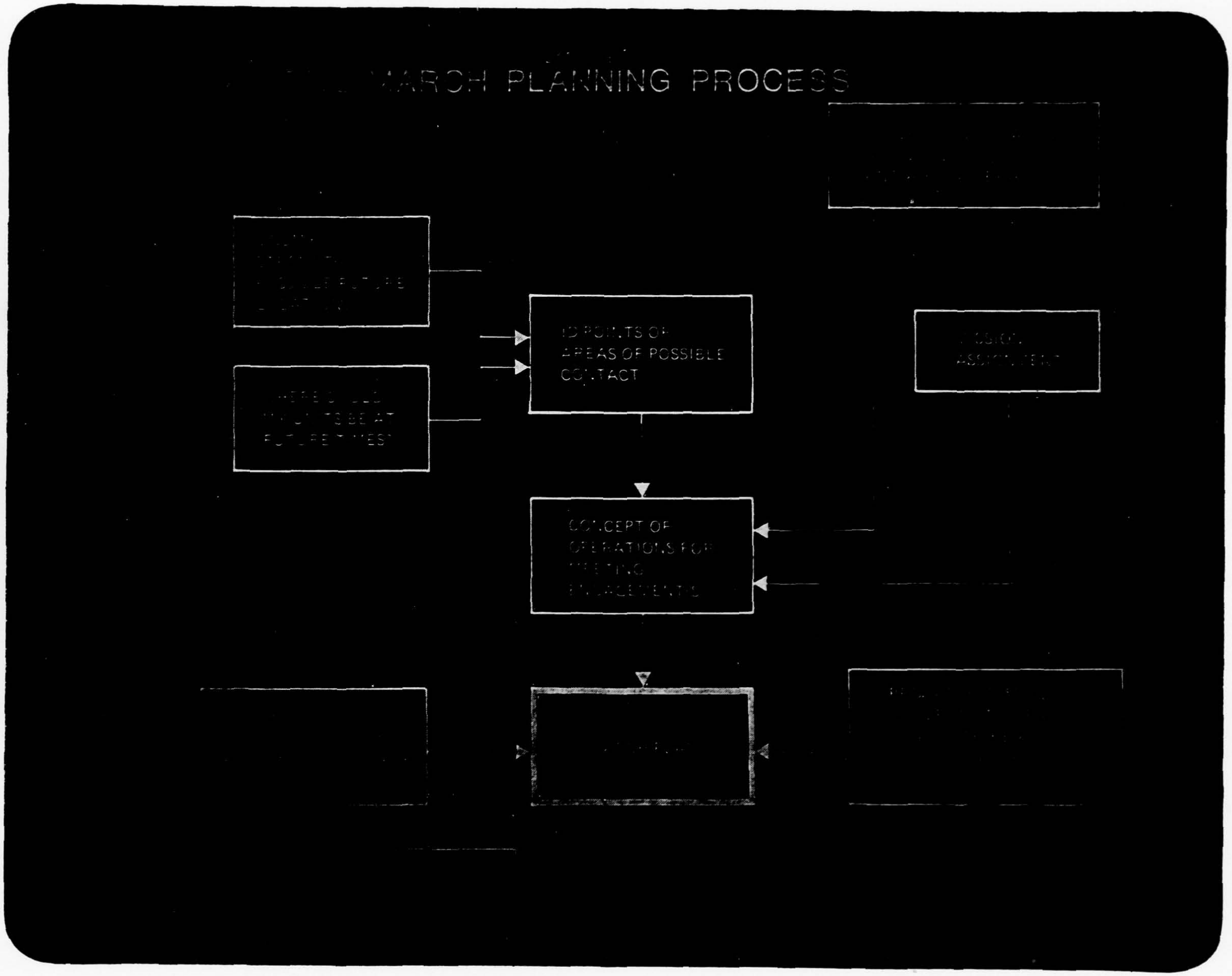
The LAMAS program architecture was built to control these models with a maximum degree of user interaction and visibility of results.


CROSS-COUNTRY MOVEMENT
FULDA GAP ROAD NETWORKS
TERRAIN MODELS
COLOR CRT DISPLAY
EXTENDED DYNAMIC PROGRAMMING
MOVEMENT UNITS
COLLECTION TASKING
MAPS
DAYTIME/ NIGHTTIME MARCH
INTERDICTION
MANUAL INTERACTION
WET/DRY ROADS AND TERRAIN
MARCH RISK
SEASONAL CONCEALMENT
MARCH TEMPLATES

HOW THE ENEMY PLANS A MARCH

The corps command must "see" the battlefield to 150 km from the FEBA. Enemy units will be marching or planning to march in the majority of this area. Careful march planning is used by the enemy to coordinate the arrival and timing of second-echelon and support units to the FEBA. Exploitation of successes at the FEBA is a popular enemy strategy and is contained in much of his military theory.

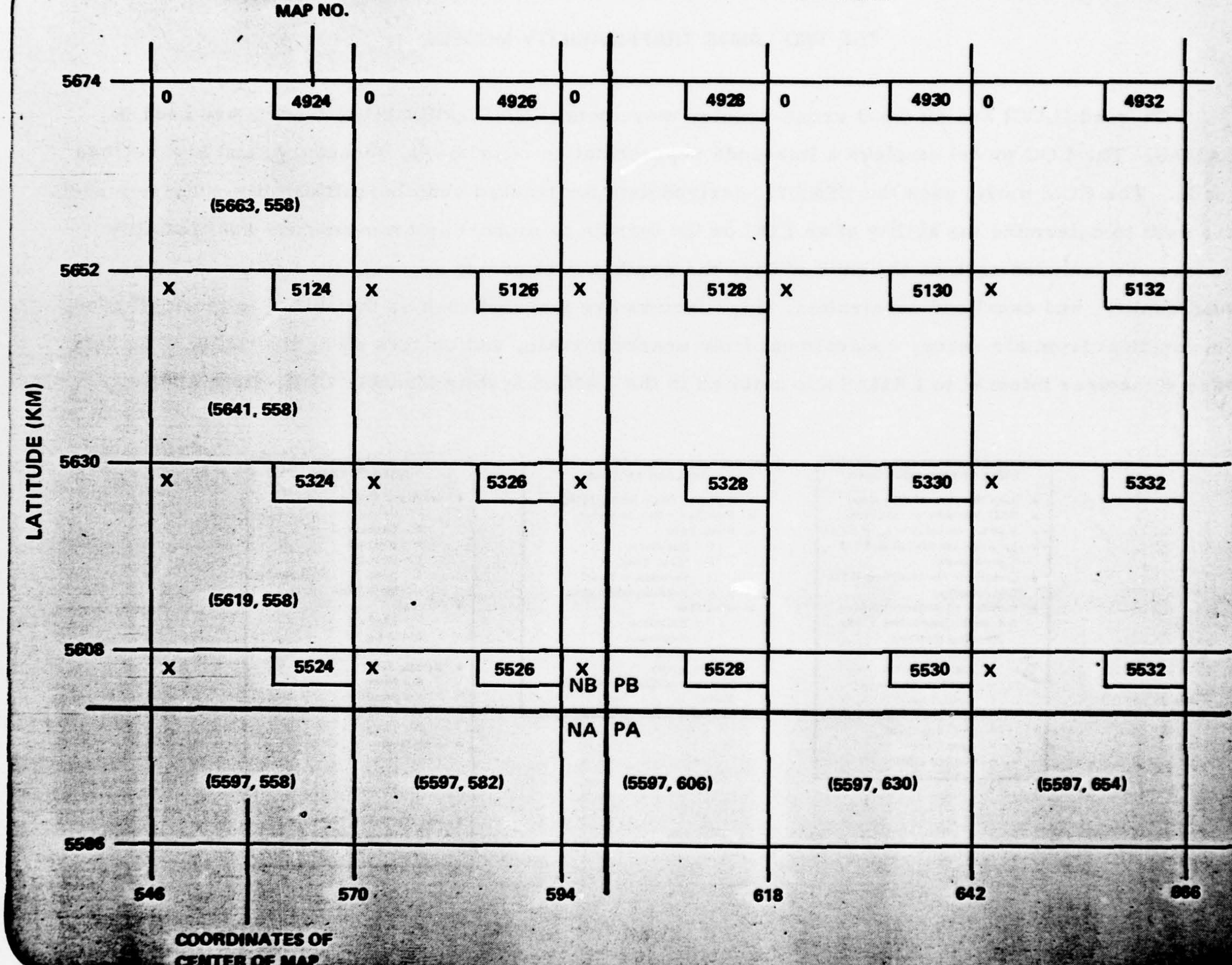
The chart on the facing page shows how the enemy plans a march for a meeting engagement. (The functions and their interrelationships were derived from special sources as well as open literature.) A key part of this plan is the coordination of movement with adjacent units, with air defense, with weather, and with minimum exposure to friendly intelligence collection and weapons, particularly nuclear. This doctrine, along with the time required for planning and execution, are modeled in LAMAS as described in the following pages. The models provide movement control of the enemy forces computed by the algorithms in LAMAS.


MARCH PLANNING PROCESS
ID POINTS OF AREAS OF POSSIBLE CONTACT
CONCEPT OF OPERATIONS FOR

AREA OF EUROPE MODELED

In order to accommodate an evaluation of LAMAS using the CACDA Command and General Staff College enemy order of battle in the Fulda Gap, an appropriate data base was constructed. For detailed resolution of the LOCs, L-series 1:50,000 maps were digitized and placed in computer storage. The chosen maps are numbered 4924, 4926, 4928, 4930, 4932, 5124, 5126, 5128, 5130, 5132, 5324, 5326, 5328, 5330, 5332, 5524, 5526, 5528, 5530, and 5532. Modified UTM coordinates — latitude represented as kilometers from the equator and longitude represented as kilometers from Greenwich — are used exclusively by LAMAS to identify a location. Thus, the total area modeled is between latitude 5586 and 5674 and longitude 546 and 666 — an 88 by 120 km area.

LAMAS MAPS DATA BASE



THE TWO LAMAS TRAFFICABILITY MODELS

On-road (LOC) and off-road cross-country movement (CCM) trafficability models are used in LAMAS. The LOC model employs a link-node representation of primary, secondary, and lower-class roads. The CCM model uses the USAETL-derived data for tracked vehicle trafficability. These models are used to determine the ability of an LOC or the terrain to support unit movement. Trafficability factors are included such as the time of day, the weather (wet or dry ground), the number of lanes, the road quality, and canalized constraints. Risk factors are included such as the ability to move off road, concealment from air recce, concealment from nearby terrain, and bridges along the route. The data base structures internal to LAMAS are detailed in the LAMAS System Manual, CDRL Item A00B.

TABLE OF LINK-NODE DATA

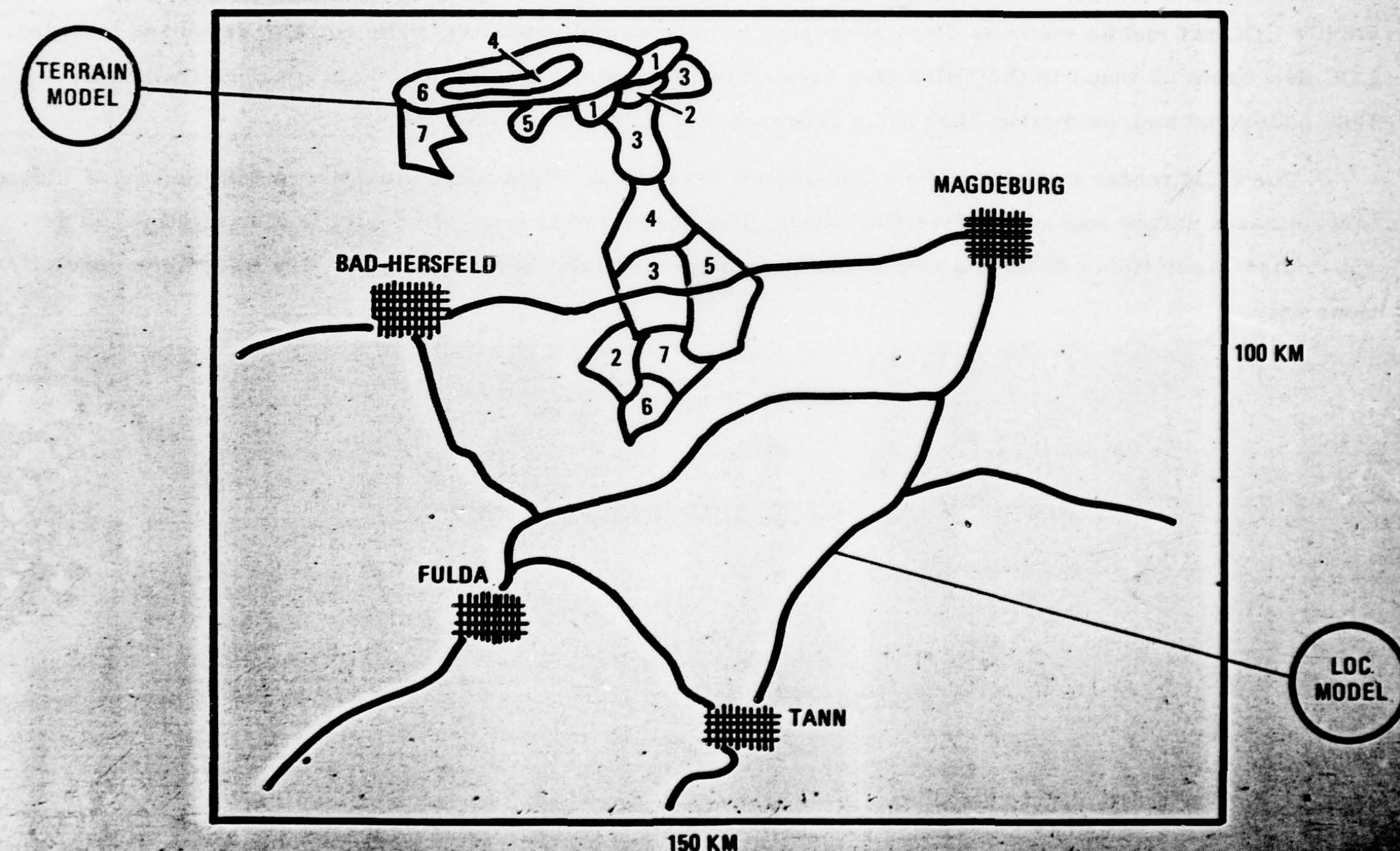
- Map Number of this Node
- Node Number of this Node
- Pointer to Solutions, *if Used*
- Latitude (in Modified UTM Coordinates)
- Longitude (in Modified UTM Coordinates)
- Number of Adjacent Nodes for Each Connecting Link:
  - Map Number
  - Node Number
  - Link Distance
  - Number of Lanes
  - Road Type
  - Off-Road Trafficability
  - Terrain Code
  - City Code
  - Bridge Code

TABLE OF FACTORS

- Time of Day – 0400, 1530, etc.
- Weather – dry or wet
- Road Type
  - 1 = Autobahn
  - 2 = Main Road
  - 3 = Secondary Road
  - 4 = Fair Weather Only
- Unit Size
  - 0 = Battalion
  - 1 = Regiment
  - 2 = Division
  - 3 = Army
- Number of Lanes – One to Four

TABLE OF RISKS

- Off-Road Trafficability
  - 1 = Urban
  - 2 = Cultivated
  - 3 = Wooded
  - 4 = Swamp
  - 5 = Road Net Adjacent to Main Link
- Terrain
  - 1 = Flat
  - 2 = Hilly
  - 3 = Mountainous
- Bridge Code
  - 0 = None
  - 1 = Small
  - 2 = Medium
  - 3 = Large
- City Code
  - 0 = None
  - 1 = Small
  - 2 = Medium
  - 3 = Large
- Intervisibility Measure
  - 10 = High Terrain Immediately to the West


TERRAIN MODEL
BAD-HERSFELD
MAGDEBURG
FULDA
TANN
LOC. MODEL
100 KM
150 KM
1
2
3
4
5
6
7

LAMAS TRAFFICABILITY MODELS ENABLE PRECISE MOVEMENT COMPUTATIONS

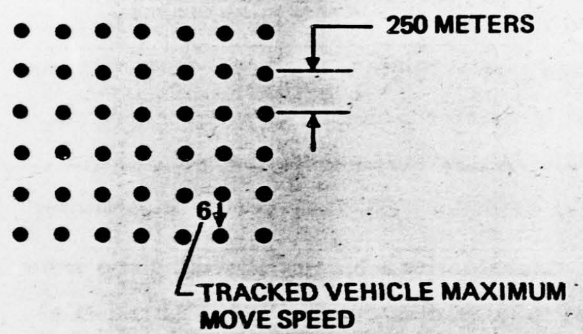
Trafficability models are detailed. On the average, the LOC model has adjacent nodes every 3 to 4 km apart. In LAMAS, a standard Army 1:50,000 scale map has as few as 40 nodes to represent a simple LOC net and as many as 75 to represent a more complicated net. The LAMAS data base includes LOC data from 20 maps in the Fulda Gap area which amounts to a total of 1000 nodes. Equivalently, 1000 nodes and approximately 2500 links represent the LOCs in a 88 by 120 km area.

The CCM model is digitized to a 250-meter resolution. This means that every 250 meters of terrain has a unique measure of trafficability. The concealment from air model is also digitized to a 250-meter resolution. CCM and concealment data are available for dry July and dry December conditions only.

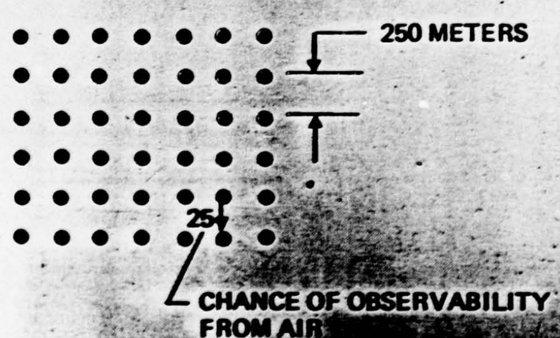
UNCLASSIFIED

MODEL TYPES

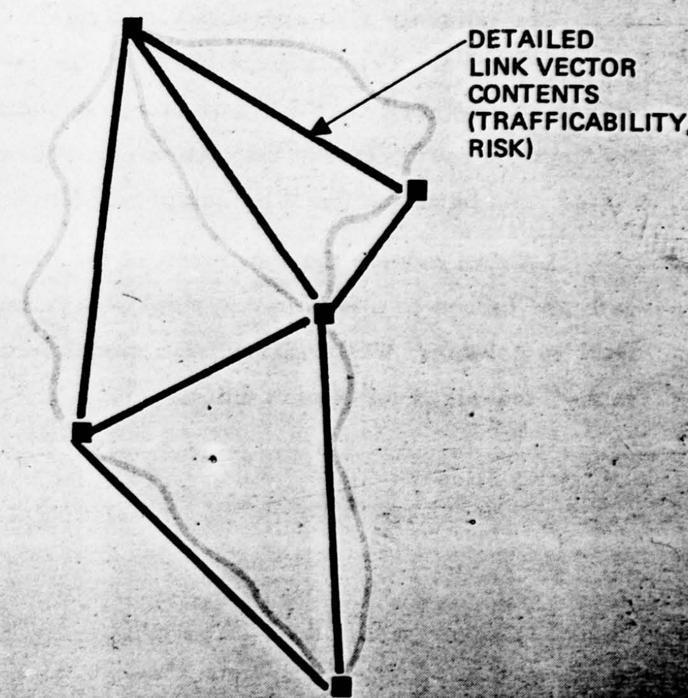
CCM MODEL



CONCEALMENT MODEL (SEASONAL)



LOC MODEL



MARCH TEMPLATES

A march template consists of an order of battle distributed in a column. If the unit is large (such as a regiment), the template accounts for the possibility that separate battalion-sized units may march on independent routes.

The template also accounts for variants due to the special deployment of subunits and reinforcement/depletion. The template shown on the facing page indicates that a single motorized rifle battalion march column may span 5 km or more depending upon the level of reinforcement. This span reflects the daytime enemy march regulation of a 500-meter nuclear-safe separation between company-sized units. The battalion could be compressed to 2 km under special conditions (such as rest at nighttime).

LAMAS models the movement of the distributed column. Multiple march units traveling the same path are forced to maintain doctrinal separation between the tail of a leading column and the head of a trailing column. While LAMAS can model columns of any length, it currently operates with battalion- to division-sized movement units.

MOTORIZED RIFLE BATTALION MARCH FORMATIONS

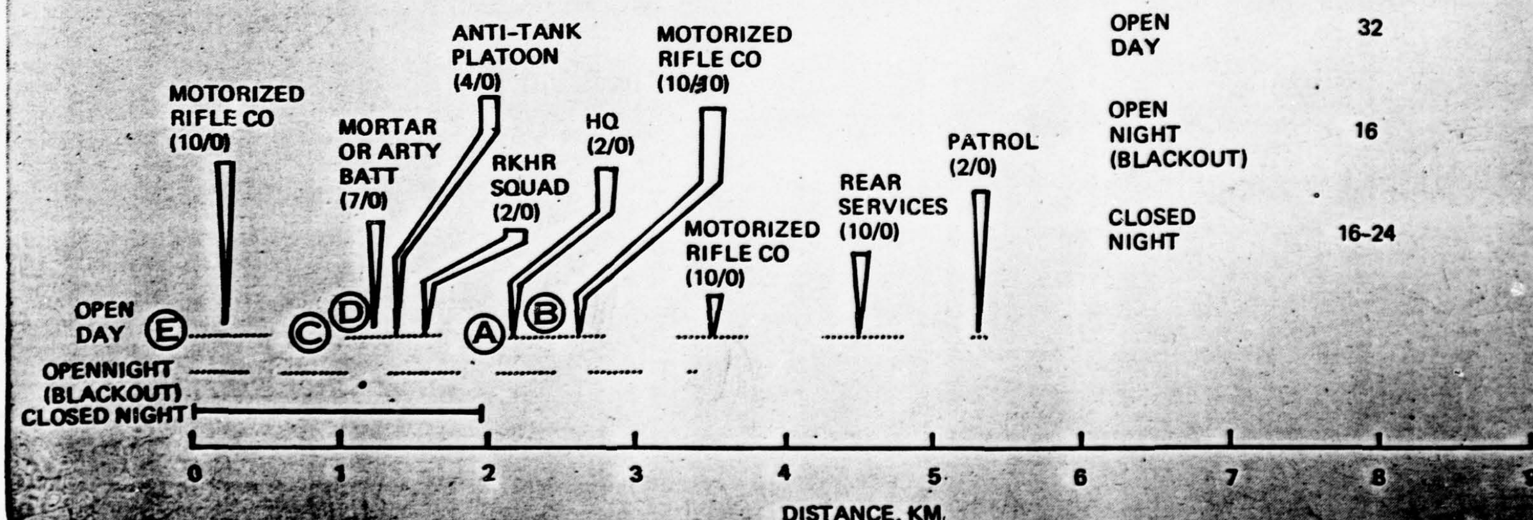
MEANS FOR REINFORCEMENT

- Ⓐ TANK COMPANY (0/13)
- Ⓑ ARTY BATTALION (65/0)
- Ⓒ ANTI-TANK BATTERY (12/0)
- Ⓓ ENGR PLATOON (5/5)
- Ⓔ RAD/CHEM RECCE SQUAD RKhR (2/0)

COMBAT RECCE PATROL IF LEADING BATTALION 5-10 KM AHEAD TO INCLUDE Ⓔ

AVERAGE SPEED (KPH)

OPEN DAY	32
OPEN NIGHT (BLACKOUT)	16
CLOSED NIGHT	16-24

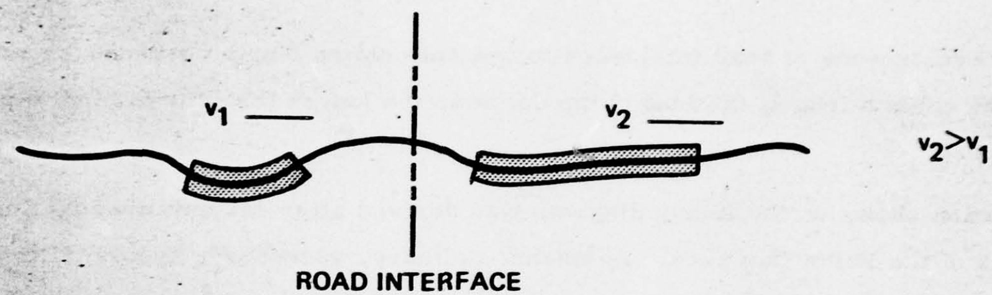


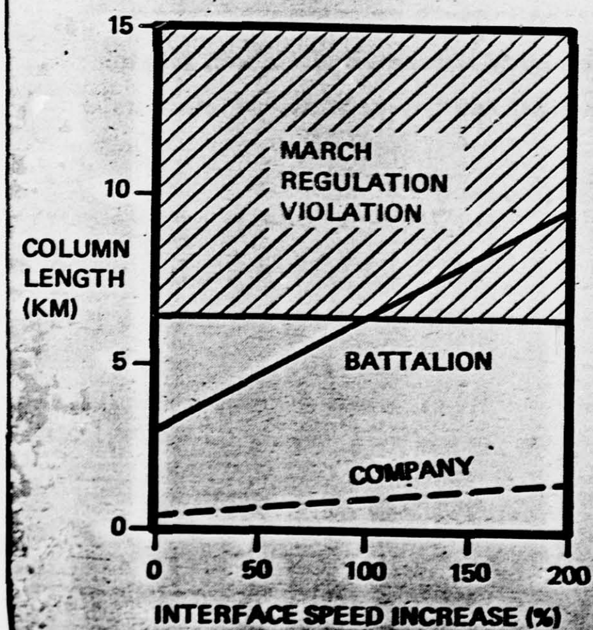
ENEMY MARCH DYNAMICS

Accurate representation of enemy march dynamics is crucial. Special information sources and open literature specify march regulations. A particular concern is control of column lengths. The diagram on the facing page shows a poor-quality road interfacing with a high-quality road. A unit cannot march as fast on the poor-quality road as on the good one. As the head of the column crosses the interface, it will pull away from the main body of the column. The result is an overall lengthening of the column — an accordion effect.

To counter this effect, the enemy adopts two basic rules: column march speeds are controlled at interfaces in fixed column lengths, and the unit is broken into subunits which march on independent routes. These rules are reflected in LAMAS by a complicated set of logic codes described in the System Manual (CDRL Item A00B).

UNCONTROLLED MARCH DYNAMICS





SOVIET MARCH REGULATIONS

- CONTROL MARCH SPEED TO FIX COLUMN LENGTHS
- BREAK COLUMN FOR PARALLEL MARCHES WITH SHORTER LENGTHS

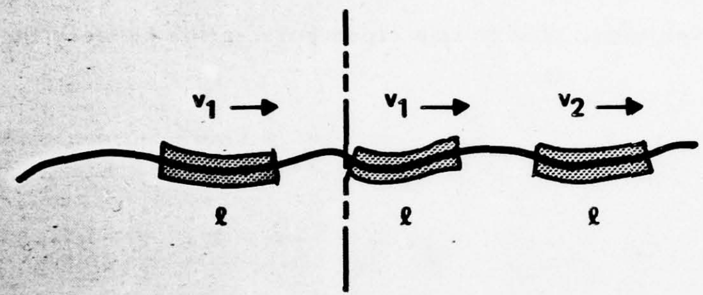
THE COST OF FIXING MARCH SPEEDS

Fixing march speeds at road interfaces to control column length costs march time. This cost is a function of the column length; the longer the column, the longer the time needed to pass an interface at a controlled speed.

The equation shown on the facing diagram was derived after careful investigation of the LOC characteristics of the Fulda Gap area. Autobahn, primary, secondary, and primitive roads were investigated to determine their lengths, tortuosity, and interfaces. Roads were broken into segments where trafficability characteristics were homogeneous. Thus, each link of an LOC is a homogeneous segment of a road.

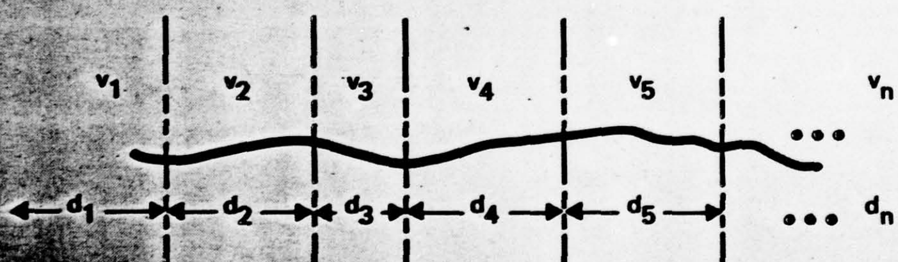
The time penalty and march control policy is built into the LAMAS march calculations. The program uses the detailed trafficability data for the links and the template extremes of column lengths for the unit type that is marching. Each link of a route has its own trafficability capacity which is used to determine the best routes.

MARCH FACTORS FOR FIXED COLUMN LENGTH



$v_2 > v_1$

EXTRA TIME COST $= \frac{\ell}{v_1} - \frac{\ell}{v_2}$



AVERAGE OF $\frac{n}{2}$ INTERFACES TO INCREASE MARCH TIME

MAXIMUM AVERAGE COLUMN SPEED $\approx \dfrac{\frac{1}{n}\sum_{1}^{n} v_i}{1 + \frac{\ell}{2} \Big/ \frac{1}{n}\sum_{1}^{n} d_i}$

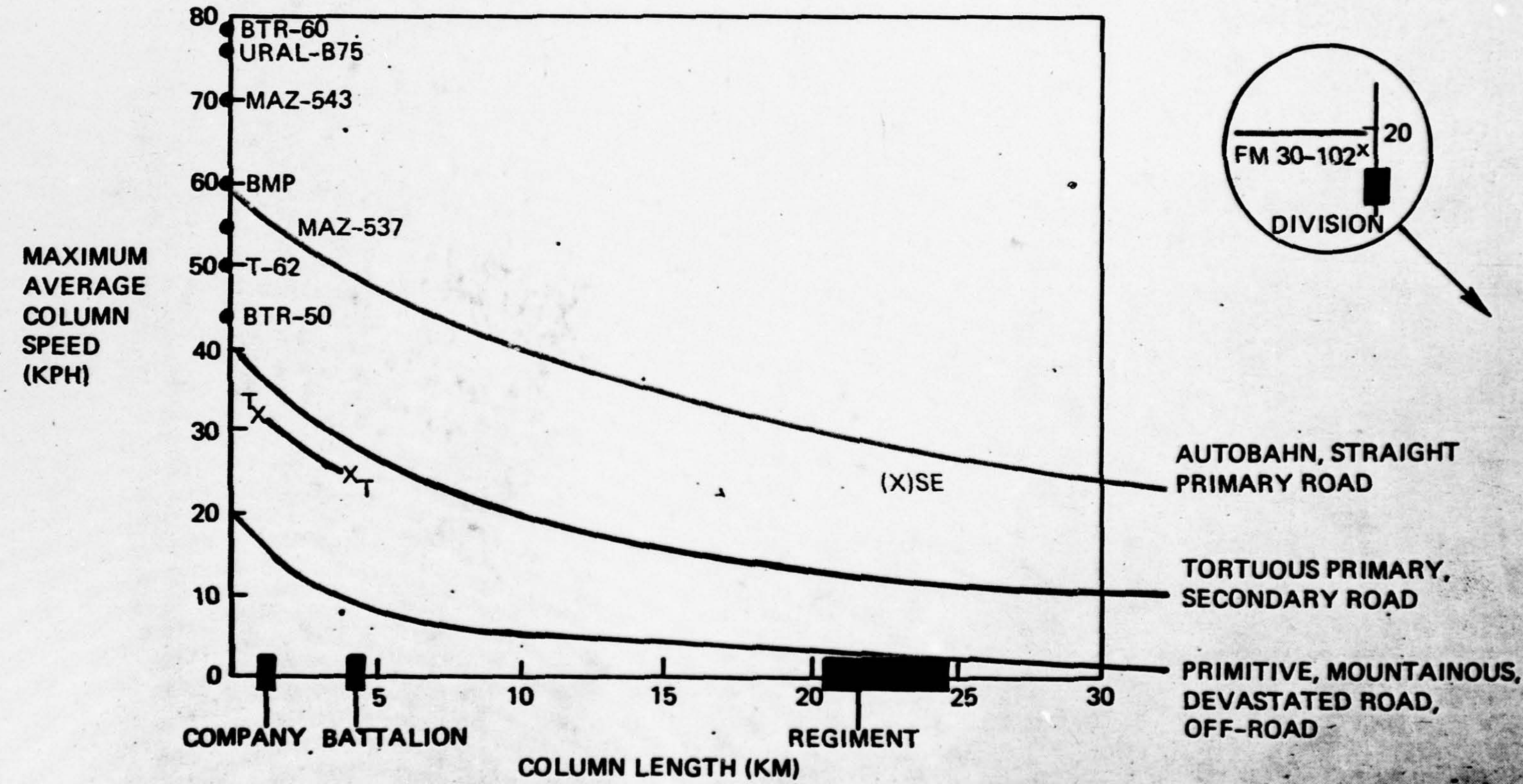
FIXED COLUMN LENGTH SPEEDS – DAYTIME

Column speeds of enemy units are shown in the facing diagram computed from the equation shown on the previous page and from road trafficability characteristics. At the left of the diagram along the y axis is the travel speed of individual enemy vehicles. There is a close correlation between the computed curves and actual data.

UNCLASSIFIED

FIXED COLUMN LENGTH SPEEDS

(DAYTIME OR LIGHTED NIGHT-TIME MARCH)



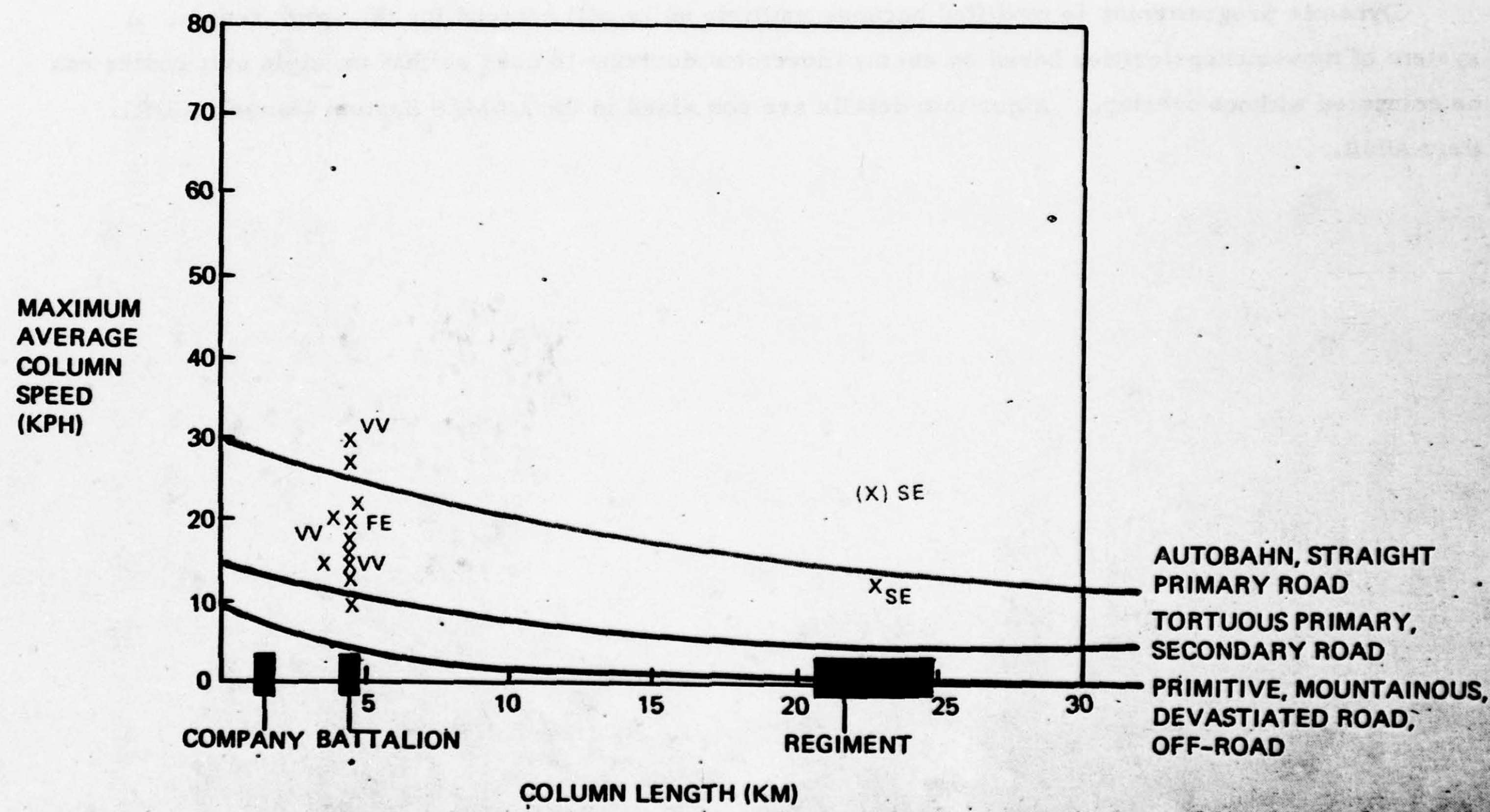
FIXED COLUMN LENGTH SPEEDS – NIGHTTIME

Column speeds are less for nighttime blackout march. The comparison of this diagram with the one on the previous page shows a degradation of 50 to 70 percent. These curves also match actual data closely.

UNCLASSIFIED

FIXED COLUMN LENGTH SPEEDS

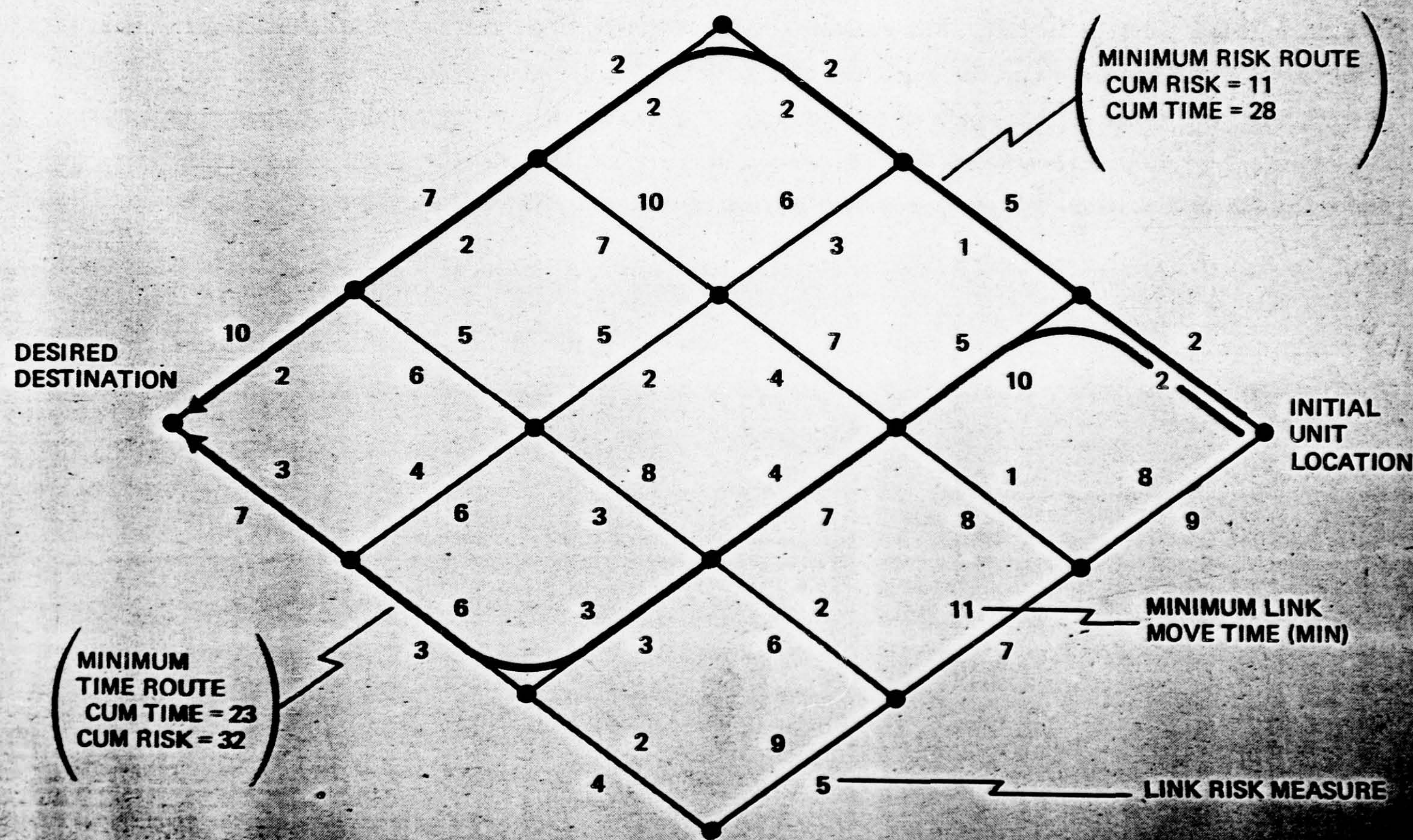
(NIGHT-TIME BLACKOUT MARCH)



THE LAMAS MOVE ALGORITHM IS MODIFIED DYNAMIC PROGRAMMING

Movement of the units along LOCs and across country is computing using modified dynamic programming. Each link has a penalty measure, both time to travel and risk (as shown in the diagram). The algorithms find optimum paths through the network in order to find minimum travel time or minimum-risk routes. On option, a weighted combination of these measures can be used.

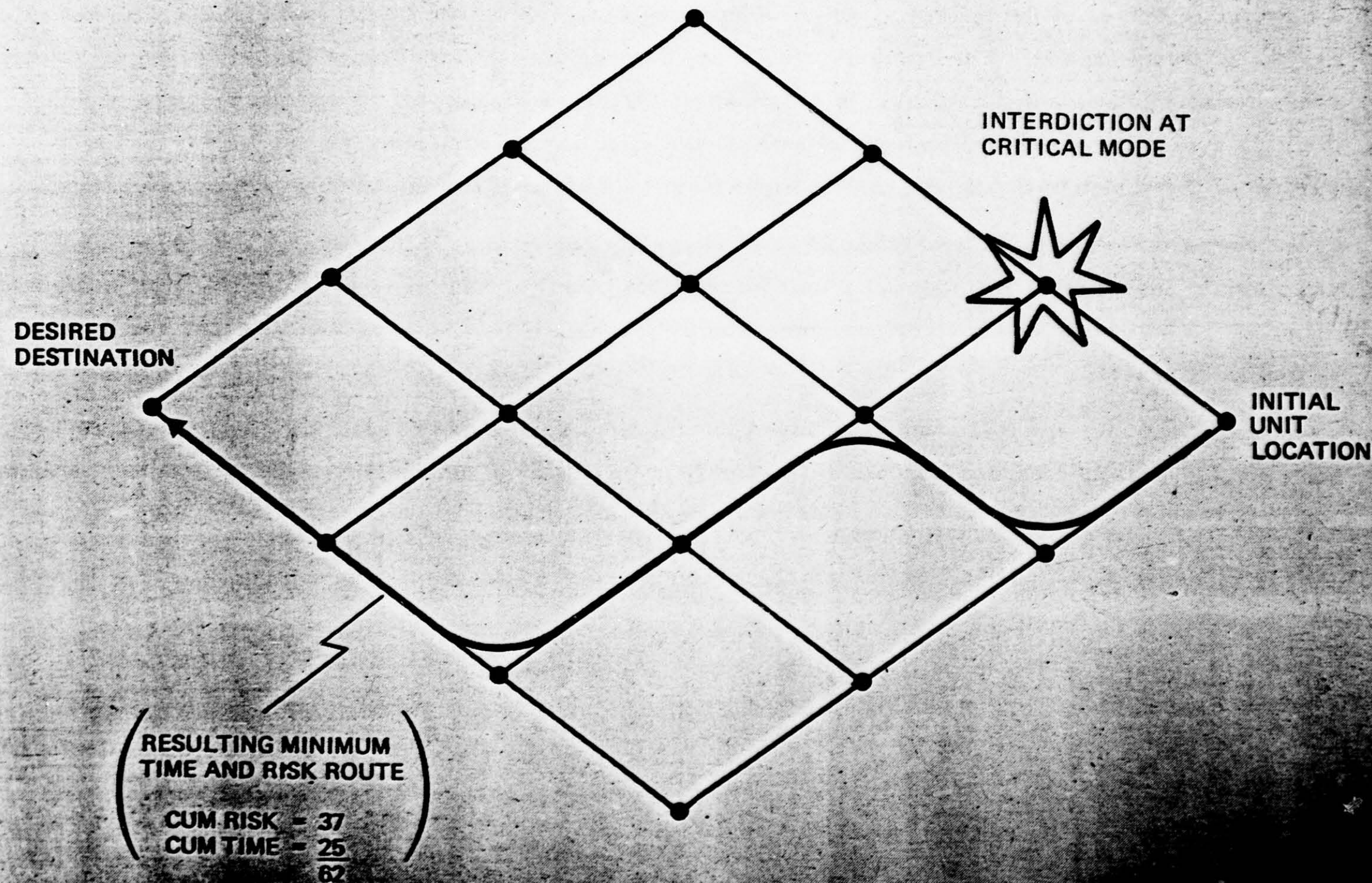
Dynamic programming is modified because multiple units will contend for the same routes. A system of movement priorities based on enemy movement doctrine is used so that multiple unit routes can be computed without overlap. Algorithm details are contained in the LAMAS System Manual, CDRL Item A00B.



MINIMUM RISK ROUTE
CUM RISK = 11
CUM TIME = 28
DESIRED DESTINATION
INITIAL UNIT LOCATION
MINIMUM TIME ROUTE
CUM TIME = 23
CUM RISK = 32
MINIMUM LINK MOVE TIME (MIN)
LINK RISK MEASURE

INTERDICTION MODEL

The link-node nature of the trafficability models enables interdiction effects to be studied by removing node(s) and/or link(s). For example, if interdiction is performed on a bridge located at a node, the node is removed and the resulting best path is found. If the bridge is on a link, the link is removed and the resulting best path is found. Enemy times to rebuild the bridge, to construct a work-around, or to perform decontamination operations in the event of a nuclear detonation are simulated by removing the link or node for an appropriate period of time and then reinstating it.



INTERDICTION AT
CRITICAL MODE
DESIRED
DESTINATION
INITIAL
UNIT
LOCATION
RESULTING MINIMUM
TIME AND RISK ROUTE
CUM RISK = 37
CUM TIME = 25
62

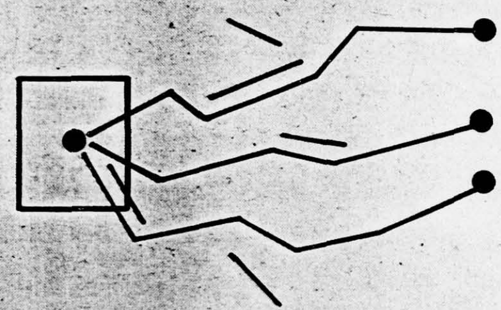
INTERDICTION PLANNING

The interdiction planning option of LAMAS is used interactively. First LAMAS is operated to find the projected routes of the individual units. These routes are inspected by the analyst to find high-risk regions of travel, if any. For example, a unit may be projected to travel on an LOC with limited adjacent cross-country movement capability. Interdiction which forces the unit off road slows the unit, and this disrupts the timing of deployment to position. Interdiction can be performed by the analyst at one or several of these high-risk regions, and the unit march time penalities can be automatically measured.

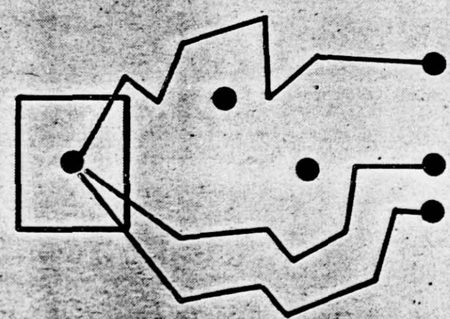
The automatic interdiction option of LAMAS can also be used. This option finds the best location and time for interdiction to maximize a unit march time penalty. Timing is very important in interdiction planning. If an enemy unit has already committed to a route, it may be very costly in time for that unit to find an alternate.

Sometimes the automatically determined interdiction location is not practical to exploit in the real world (e.g., heavily defended with air defense units). In this case the analyst modifies the solution using manual overrides.

INTERDICTION PLANNING



- ROUTES ARE ESTABLISHED USING ALGORITHMS
- HIGH RISK LINKS ARE DETERMINED AND INDICATED TO USER



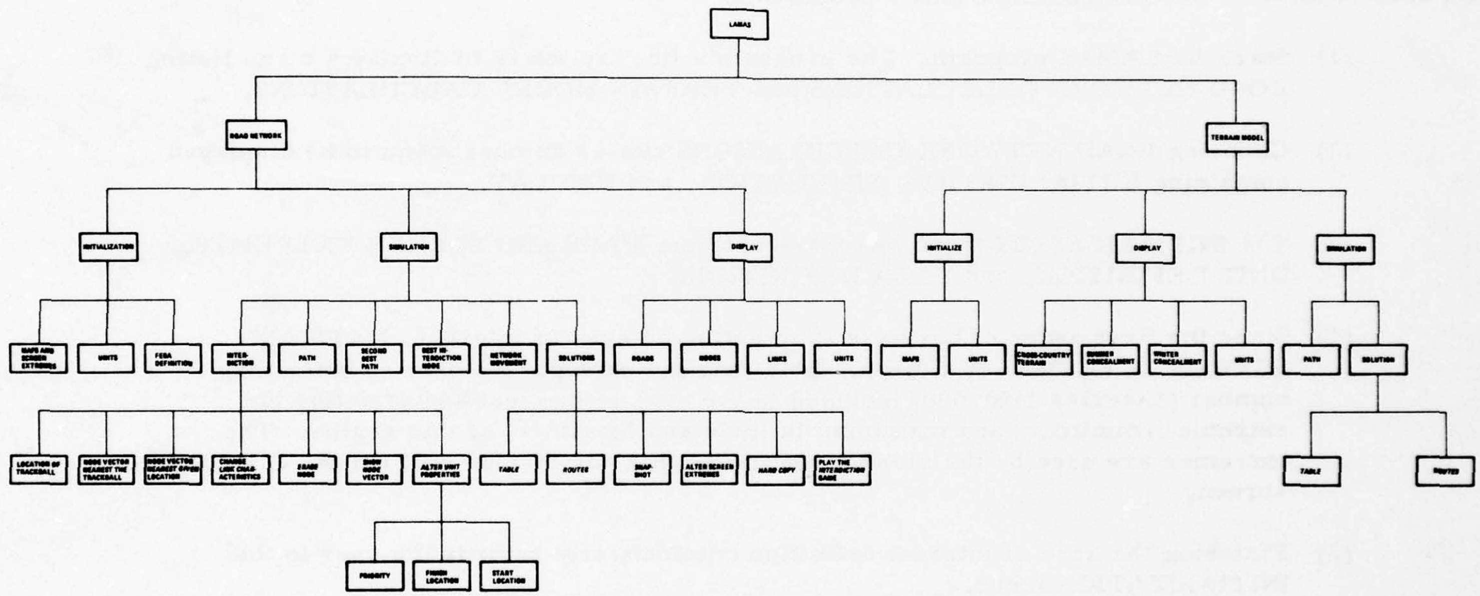
- TIME PHASED INTERDICTION IS USED TO DISRUPT MOVEMENT
- NEW ROUTES AND TIME OF ARRIVAL AT DESTINATION ARE DETERMINED
- ALGORITHMS ARE USED INTERACTIVELY TO ESTABLISH WHEN AND WHERE INTERDICTION WILL BE MOST EFFECTIVE

6. THE LAMAS SOFTWARE STRUCTURE - OVERVIEW

LAMAS is a highly modular programming system illustrated by this block diagram of the LAMAS functions. Its primary method of communicating with the user is a menu from which the user may choose a desired function. Each horizontal line of functions on this diagram corresponds to a menu entry. For example, the first menu has two entries, ROAD NETWORK and TERRAIN MODEL. Depending upon which is chosen, a new menu will appear. Eventually the user will choose a function which performs a certain task (such as displaying a road map or calculating a path). When this situation arises, the user is prompted to enter appropriate data at the terminal. Once all necessary data are obtained, the function will perform its task, display or print output, and then return to display the menu which contains the just-used function.

Proceeding in the manner described, the user may perform many diverse calculations and analyses of situations. As an example of how a series of functions may be used to perform a calculation, the following pages describe one method of calculating a simple path, displaying the calculated route, displaying the road network used, and printing out on a line printer.

LAMAS PROGRAM STRUCTURE



ESTABLISHING THE CONDITIONS

To start the process of calculating a single path, the conditions must be set. This includes defining an area of interest and designating a unit's properties.

(1) Start the LAMAS program. The program's first action is to display a menu listing ROAD NETWORK CALCULATIONS and TERRAIN MODEL CALCULATIONS.

(2) Choosing ROAD NETWORK CALCULATIONS causes another menu to be displayed containing INITIALIZATION, SIMULATION, and DISPLAY.

(3) The INITIALIZATION menu has three entries: MAPS AND SCREEN EXTREMES, UNIT DEFINITION, and FEBA DEFINITION.

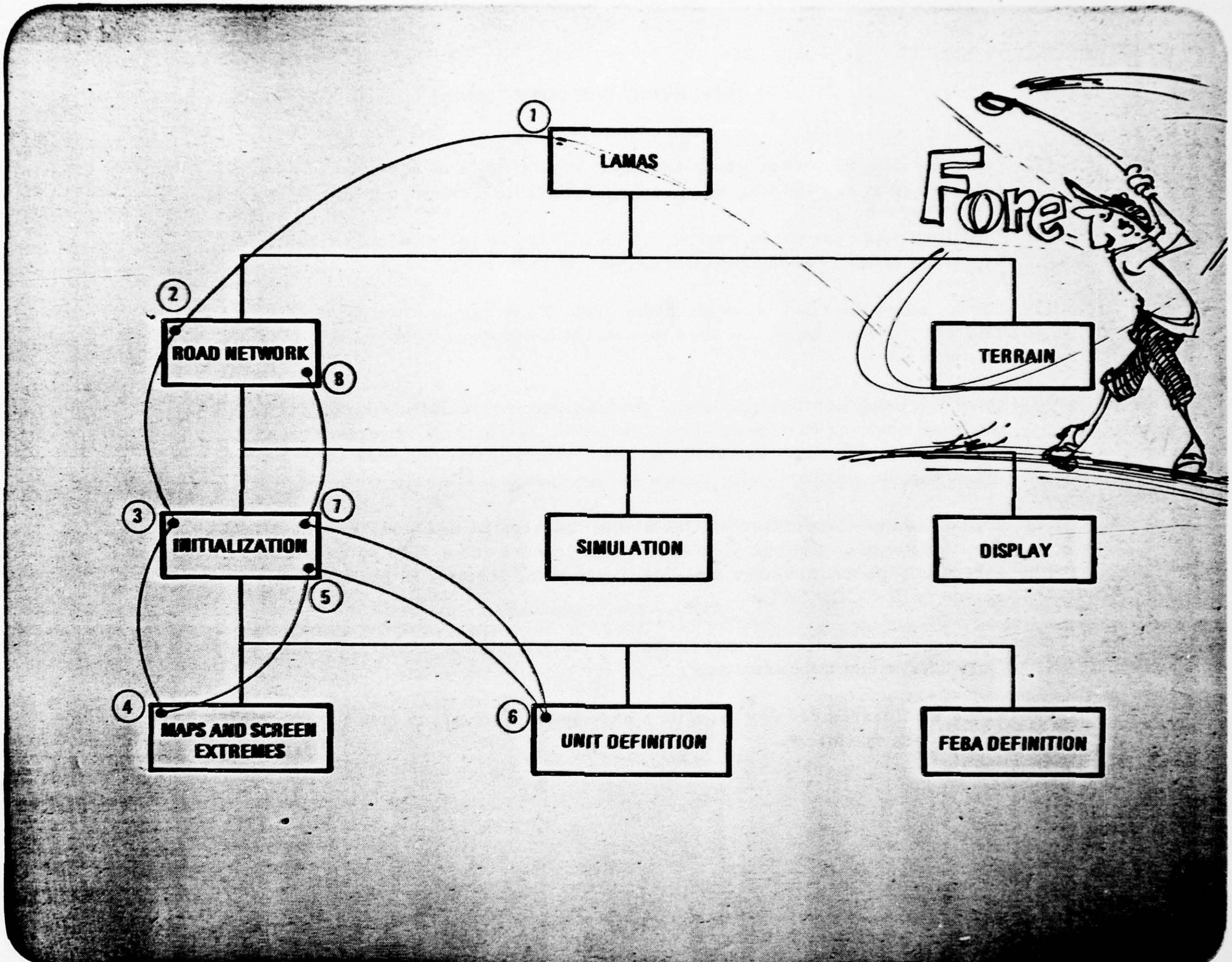
(4) Since the first order of business is to define an area of interest, MAPS AND SCREEN EXTREMES is chosen. This function prompts the user to enter map number (L series 1:50,000) included in the area of interest and to define the extremes (minimum and maximum latitude and longitude) of this region. The extremes are used by the display routine so that any display will fill the COMTAL screen.

(5) Finishing the area of interest definition automatically returns the user to the INITIALIZATION menu.

(6) Next, choose UNIT definition so that the ground force may be set up. Prompts are given to help the user enter all appropriate data such as unit name, starting location, stopping location, priority of movement, and unit type (motorized rifle battalion, tank regiment, etc.).

(7) When the unit has been defined, the INITIALIZATION menu automatically reappears.

(8) The conditions have been established, so return to the ROAD NETWORK menu.


LAMAS
ROAD NETWORK
TERRAIN
INITIALIZATION
SIMULATION
DISPLAY
MAPS AND SCREEN EXTREMES
UNIT DEFINITION
FEBA DEFINITION
Fore
1
2
3
4
5
6
7
8

DISPLAYING THE CONDITIONS

(1) Once the conditions are established, it is desirable to see what has been selected to run. Starting at the ROAD NETWORK menu, choose DISPLAY.

(2) DISPLAY has four menu items. Each will cause the particular item to be shown on or erased from the COMTAL screen.

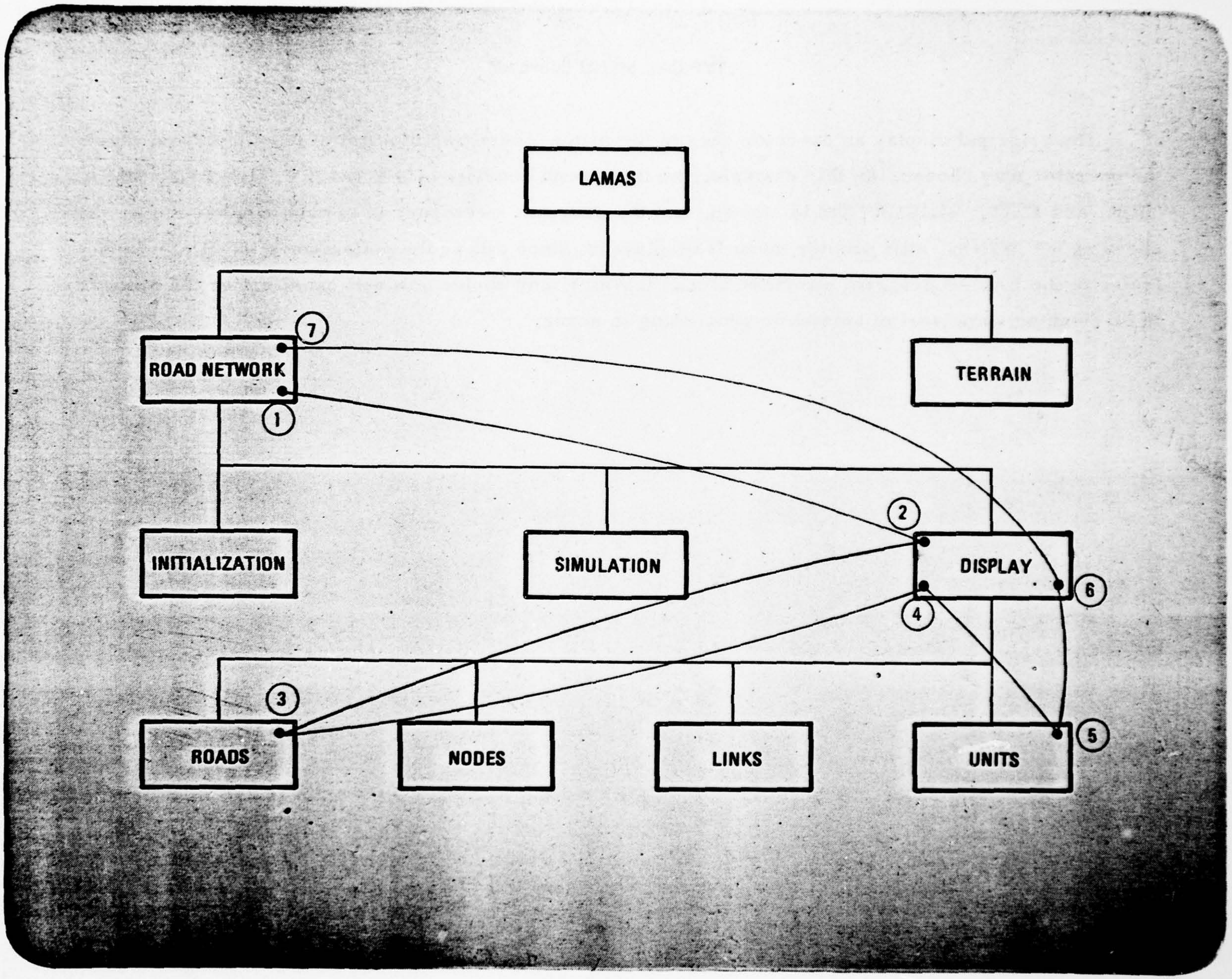
(3) First, show the road network of the area of interest. Choose ROADS. The program prompts the user to specify if displaying or erasing is to be done.

(4) Once the user finishes the input, the computer calculates which part of the road network data base should be used, and after a several-second wait, the area of interest is displayed. When completed, the DISPLAY menu will be automatically shown on the user's terminal.

(5) To see where the defined unit is within the area of interest, choose UNITS. The user will be prompted to enter a unit name and a display or erase direction. In response to a display response, the unit is immediately shown on the COMTAL.

(6) When the user indicates that there are no more units to be displayed, the DISPLAY menu appears again.

(7) Since all desired display functions have been invoked, return to the ROAD NETWORK menu.


LAMAS
ROAD NETWORK
TERRAIN
INITIALIZATION
SIMULATION
DISPLAY
ROADS
NODES
LINKS
UNITS
1
2
3
4
5
6
7

TYPICAL MENU DISPLAY

The principal display an operator sees is the menu, consisting of a list of functions from which the operator may choose. In this example, the first menu consists of INITIALIZE, DISPLAY, SIMULATION, and EXIT. SIMULATION is chosen, and the program's response is to print another menu. After choosing SOLUTION, still another menu is displayed. Since this is the bottom-most level of menus (refer to the LAMAS program structure block diagram), any choice now will cause either the prompters to be given or some sort of automatic processing to occur.

```
INITIALIZE
DISPLAY
SIMULATION
EXIT
SI
TO INITIATE A FUNCTION, ENTER ITS FIRST TWO LETTERS
INTERDICTION
PATH
SECOND BEST PATH
SHORTEST LONG PATH
BEST INTERDICTION NODE
SOLUTION
EXIT
IN
TO INITIATE ANY FUNCTION, ENTER THE FIRST TWO LETTERS
[illegible]
[illegible]
[illegible]
[illegible] SCREEN EXTREMES
[illegible] OF RESULTS
[illegible] INTERDICTION GAME
[illegible] FOR TEMPO
```

CALCULATING THE PATH

(1) Looking at the ROAD NETWORK menu, one sees INITIALIZATION, SIMULATION, and DISPLAY. The area of interest and ground force scenario have been established and displayed. It's time to get down to business and calculate a path.

(2) Choose SIMULATION of the six functions available; four will calculate paths, but only one calculates best paths.

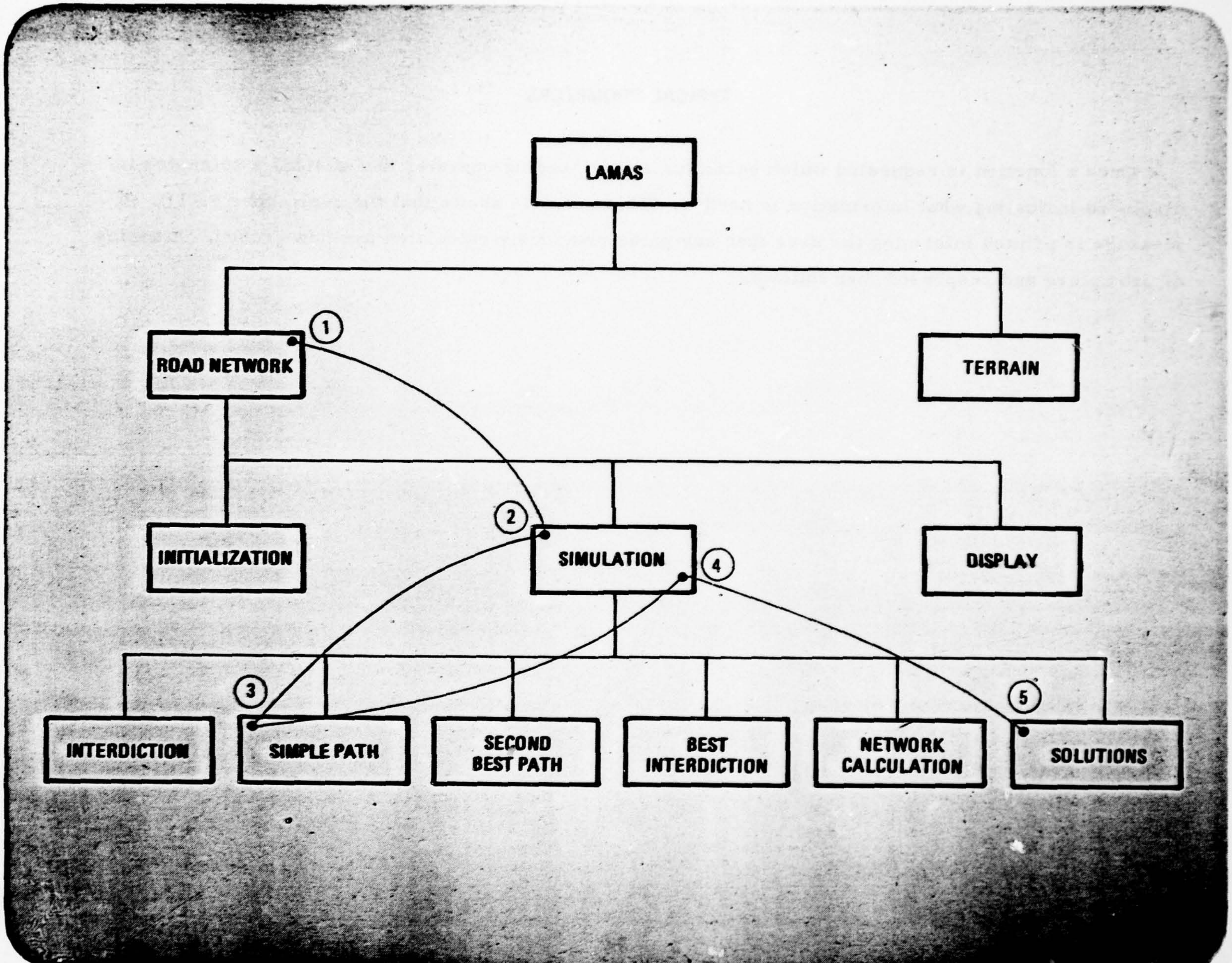
(3) Choose PATHS. Now starts a series of prompters which afford the user a great deal of flexibility. The first choice is movement type, forward or backward. Each type has significance, with the basic difference being that backward answers the following question: At what time must a unit leave its starting location to arrive at its destination at a given time? Forward time movement allows the user to specify the starting time. For this case, choose forward time movement.

Next, should conflict resolution be performed? This means that if two units try to occupy an area at the same time, only one may do so. The other unit must either wait for the first to clear the area or go around. A unit's priority table decides which unit goes first. For an example, choose conflict resolution (for only one unit it really doesn't make any difference). Then establish the weather conditions, either dry or wet. This affects unit movement as some roads are fair-weather roads only, and certainly mobility is decreased with inclement weather.

The path being calculated is a "best" path, where best is a user-defined function of risk and time. At this point, the user is asked to indicate his definition of "best." This is done by entering a numerical factor for risk and time (that is, the letter A and B in the equation A x risk + B x time). This establishes a weighted correspondence between the two measures. Then the user enters the names of all units which are to have paths calculated; in this case, just the one name. Finally, the user enters the units' starting or stopping times (depending on movement type), and the path is then calculated.

(4) When the path has been calculated, a message is printed to that effect and the SIMULATION menu reappears.

(5) It's time to see the results of the path calculation, so choose SOLUTIONS.


LAMAS
ROAD NETWORK
TERRAIN
INITIALIZATION
SIMULATION
DISPLAY
INTERDICTION
SIMPLE PATH
SECOND BEST PATH
BEST INTERDICTION
NETWORK CALCULATION
SOLUTIONS
1
2
3
4
5

TYPICAL PROMPTERS

Once a function is requested which performs a task needing operator interaction, a prompter is displayed indicating what information is needed. This example shows that the user chose PATH. A message is printed informing the user than any paths previously calculated are now erased. A series of prompters and responses then follows.

[illegible] PATHS ARE BEING PURGED.

[illegible] TO MOVE FORWARD IN TIME, OR ENTER
[illegible] BACKWARD IN TIME. TO EXIT, ENTER (CR).

[illegible] DESIRE CONFLICT RESOLUTION, ENTER
[illegible] ANY OTHER NUMBER.

[illegible] FOR DRY ROAD CONDITIONS, OR WE FOR WET.

[illegible] CALCULATION USES A COMBINATION OF RISK AND TIME
[illegible] RISK + K*TIME. IT IS UP TO THE
[illegible] THE VALUES OF [illegible] AND K. [illegible] MAY BE EITHER
[illegible] RANGE BETWEEN 0 AND [illegible].99 .

DISPLAYING THE RESULTS

(1) The path has been calculated, so it is now time to see what results the program generated. Choose TABLE.

(2) Upon invocation, TABLE prints a table of unit names and the corresponding route number on the terminal. Thus, for this example, the unit name and a "1" would be printed.

(3) TABLE does its work and automatically returns to the SOLUTION menu. Now let's display the calculated route on the COMTAL. To do this, choose ROUTES.

(4) The user is first prompted to choose a color for display and then to enter a route number. This number corresponds to the associated route number displayed by TABLE. Once entered, the user chooses display or erase, and *the desired route is so manipulated.*

(5) When the user indicates no more routes of interest, the SOLUTION menu is once again displayed on the terminal. The final function to be used for this example is HARD COPY. Choose HARD COPY.

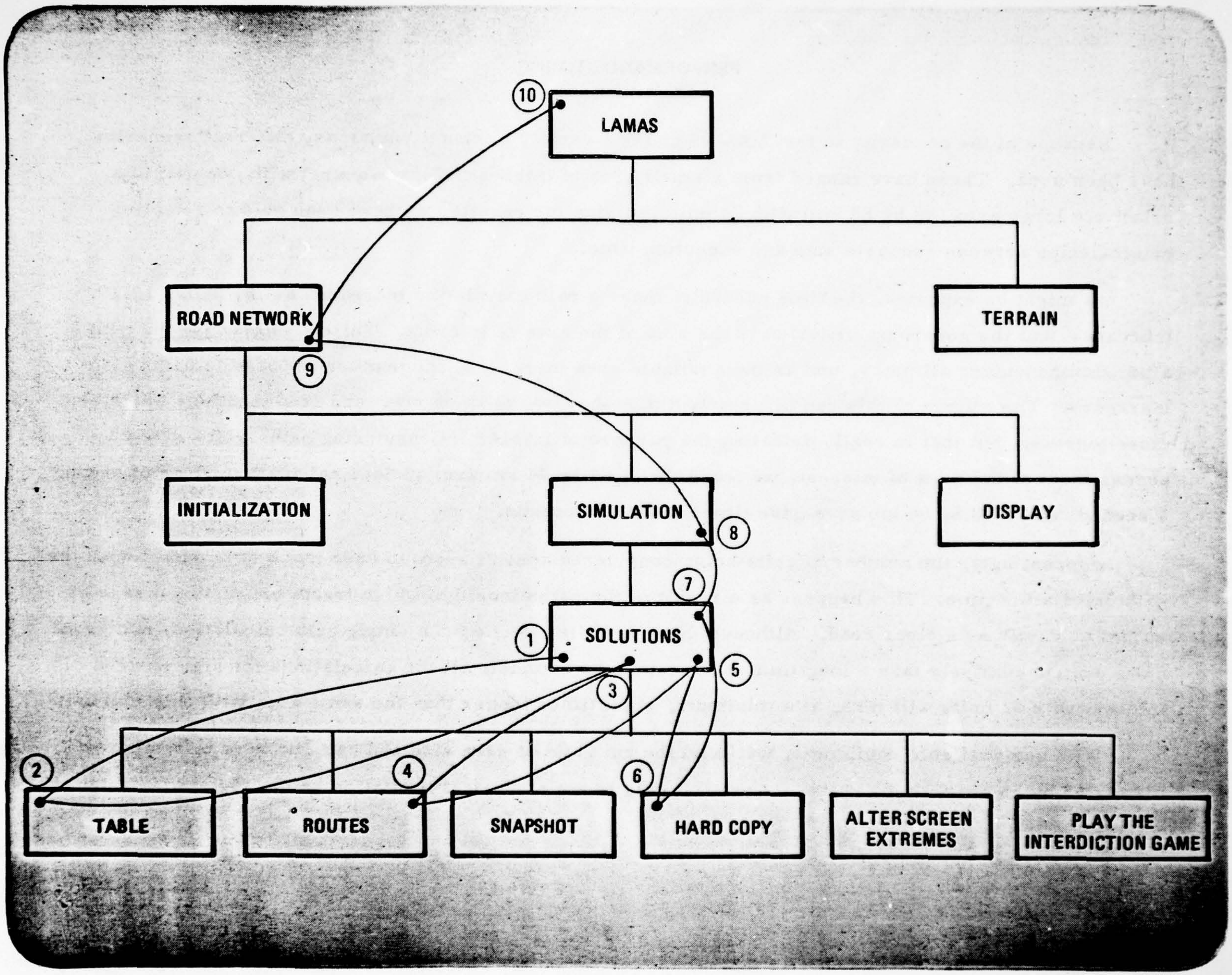
(6) This function causes path statistics (start and stop locations, start and stop times, route distance, etc.) to be automatically printed on the line printer.

(7) After this, the SOLUTION menu is shown. We are done, so return to the SIMULATION menu.

(8) From the SIMULATION menu, exit to the ROAD NETWORK menu.

(9) Now return to the LAMAS menu.

(10) We are back at the beginning.


LAMAS
ROAD NETWORK
TERRAIN
INITIALIZATION
SIMULATION
DISPLAY
SOLUTIONS
TABLE
ROUTES
SNAPSHOT
HARD COPY
ALTER SCREEN EXTREMES
PLAY THE INTERDICTION GAME
1
2
3
4
5
6
7
8
9
10

AD-A067 621 TRW DEFENSE AND SPACE SYSTEMS GROUP REDONDO BEACH CALIF F/G 15/7
LOCATION AND MOVEMENT ANALYSIS SYSTEM (LAMAS).(U)
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PERFORMANCE/TIMING

Because of the necessity to test LAMAS under a variety of conditions, many different scenarios have been used. These have ranged from a small area of interest (10-km square) with one unit to a relatively large area (88 by 88 km) with 34 units. Using the results, we have been able to establish relationships between scenario size and execution time.

As might be expected, the time needed to make a path calculation increases as the path's length increases, but the governing criterion is the size of the area of interest. This is so because the path algorithm considers all paths, and as the available area increases, the number of possible paths also increases. The effects of this can be greatly diminished by selecting start and stop locations which are close together, but that is really defeating the purpose of LAMAS. Considering paths which stretch across most of the area of interest, we found that a 44 by 44 km area yielded calculation times of around 1 second, and a 88 by 66 km area gave times of 2 to 3 seconds.

Interestingly, the number of units being considered doesn't seem to have much of an effect upon the path calculation time. This happens as a result of the path algorithm which treats congestion (usage of roads) as easily as a clear road. Although there is little effect upon a single path calculation, numerous units can cumulatively take a long time to execute. To complete all the calculations for a given area of interest with 32 units will take, at a minimum, eight times longer than the same area with only four units.

With our available equipment, we found the best mix of area size and unit numbers to be approximately 55 by 55 km with six units. Certainly this is not a physical limitation as the system is designed

to handle 60 units over an 88 by 88 km area, but for visual registration on the display and timeliness, the smaller area and ground force is more desirable. The area is large enough to be able to supply answers to a commander's questions regarding axes of attack and sensor tasking, without being too small as to be limited in its scope. The number of units is enough to present a real situation (e.g., a division preparing to attack), yet not so large as to clutter the display screen. With the 34-unit scenario, the solutions computed were quite reasonable, but the display was difficult to read. It was necessary to look at the hard-copy output and manually construct tables so that the results could be analyzed. The operator time involved in performing the large scenario was not prohibitive, but tended to be tedious, particularly when trying to make different calculations for each unit.

An operational installation in support of a corps-level command should contain multiple LAMAS stations. This would allow the battlefield to be broken up and analyzed separately with less time expended. A 20 by 20 km area could be continuously analyzed at a single station. Six to ten units in this area could represent battalions and lower. This division of effort is not unlike the separation of areas used in air traffic control.

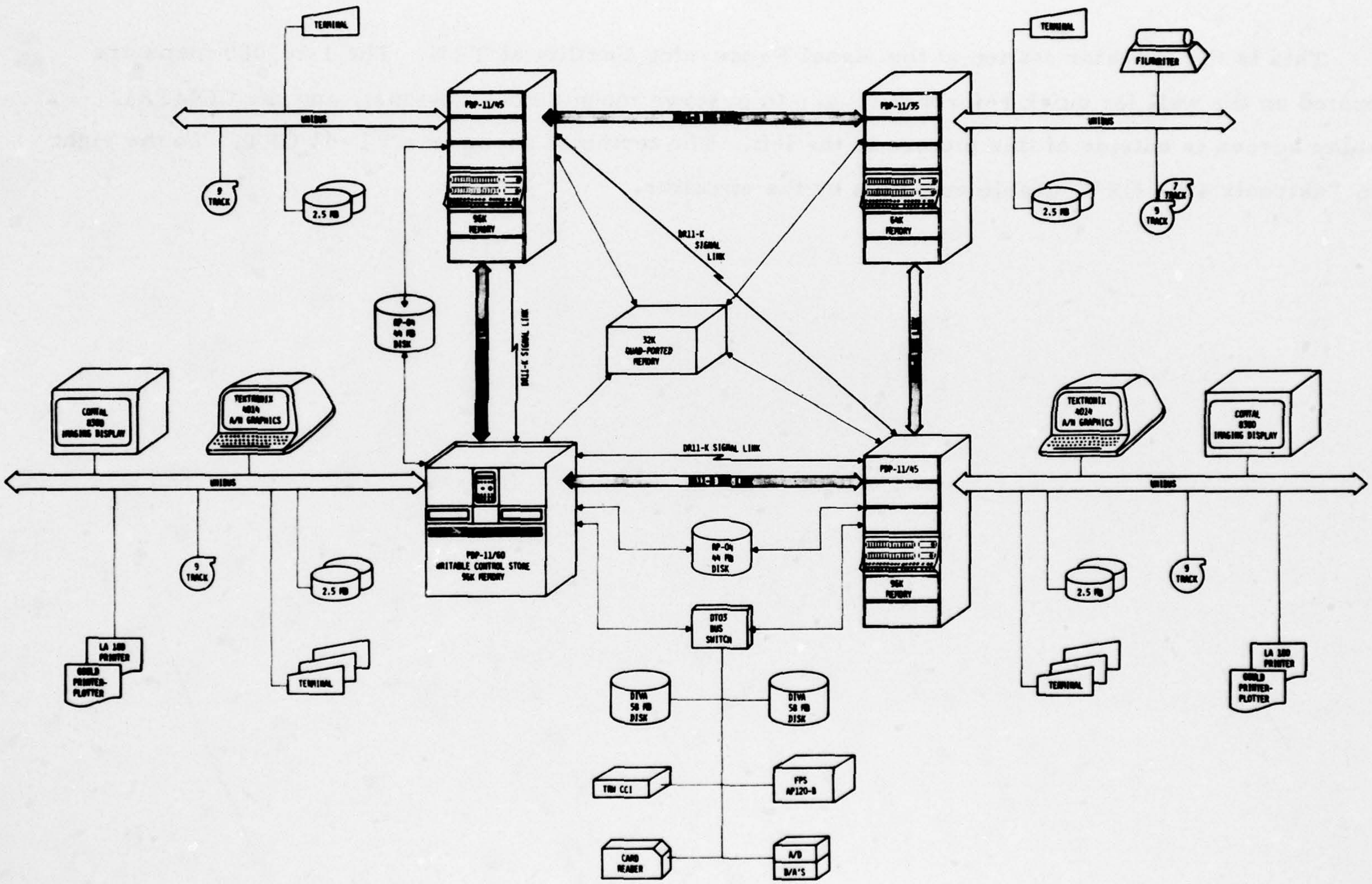
In summary, it was found that the single path calculation time increased as the area of interest increased, but that the real-time impact which occurred was due to how many paths needed to be calculated. The most comfortable area of interest and number of units scenario using visual and analytical criteria was an approximate 55 by 55 km area with six to ten units.

7. SYSTEM HARDWARE

The system hardware configuration at the Signal Processing Facility where LAMAS was implemented consists of four computers — a PDP-11/60, two PDP-11/45s, and a PDP-11/35 with links between each other as shown. LAMAS works on either the PDP-11/60 or the lower-right PDP-11/45. Each of these machines has a number of peripherals available, but LAMAS only uses a COMTAL 8300 imaging display, the RP-04 disk, and either a Tektronix 4014 CRT or one of the Decwriter terminals. All hard-copy output is printed on the Gould printer-plotter.

A version of LAMAS was also constructed to operate on the CDC-6500 general-purpose computer. This version of LAMAS was installed at CACDA and has been integrated to operate with the CORP TOS by another contractor.

TRW SIGNAL PROCESSING FACILITY



OPERATOR STATION

This is the operator station at the Signal Processing Facility at TRW. The 1:50,000 maps are mounted on the wall for quick reference (e.g., to observe mountainous regions), and the COMTAL display screen is outside of this picture to the left. The terminal shown is a VT-52 CRT. To the right is a Tektronix 4014 CRT, usable on option by the operator.